BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

REPORT

OF THE

NINETY-SIXTH MEETING

(NINETY-EIGHTH YEAR)

GLASGOW—1928

SEPTEMBER 5–12

LONDON

OFFICE OF THE BRITISH ASSOCIATION
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THE CHARTER

OF THE

British Association for the Advancement of Science

GEORGE THE FIFTH by the Grace of God, of Great Britain, Ireland and the British Dominions beyond the Seas, King, Defender of the Faith, Emperor of India :

To all to whom these Presents shall come, Greeting !

Whereas in the year One thousand eight hundred and thirty-one a Voluntary Association known as the British Association for the Advancement of Science was formed to give a stronger impulse and a more systematic direction to scientific inquiry ; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers ; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress :

And Whereas the said Voluntary Association hath through its duly authorised Officers petitioned Us for a Charter of Incorporation such as is in and by these Presents granted :

And Whereas We are minded to comply with the prayer of such petition :

Now, Therefore, We, by virtue of Our Royal Prerogative in that behalf, and of all other powers enabling Us so to do of Our Special Grace, certain knowledge, and mere motion do hereby, for Us, Our Heirs, and Successors, will, grant, direct, appoint, and declare to the said Voluntary Association as follows :—

1. The persons now members of the said Voluntary Association and all such persons as shall hereafter become members of the Association hereby incorporated shall be one Body Corporate and Politic by the name of "The British Association for the Advancement of Science" and by that name shall and may sue and be sued, plead and be impleaded in all Courts whether of law or equity either in Our United Kingdom or in Our Dominions, Colonies or Dependencies and shall have perpetual succession and a common seal which may be changed or varied by it at its pleasure :

And We do Hereby Further Grant and Ordain that the said British Association for the Advancement of Science (hereinafter called "the Association") shall have and may exercise all or any of the powers, rights, authorities, and privileges and shall be subject to the duties and obligations hereinafter set forth and shall be entitled to the benefit of and be subject to the provisions hereinafter contained and such provisions shall have effect accordingly.

2. The Association shall have power to acquire, take over and accept by way of gift from the Existing Association all the property, stocks, funds, securities and other assets of every description now belonging to the Existing Association or held in trust for or for the use of the same and to undertake, execute and perform any trust or conditions affecting any of such property, stocks, funds, securities or other assets and to give any trustees in whom the same may be vested a valid receipt, discharge and indemnity for and in respect of the transfer of the same to the Association.

3. We do also hereby, for Us, Our Heirs, and Successors, license, authorise, and for ever hereafter enable the Association to purchase, take on lease or hire, accept on loan or as a gift or otherwise acquire or hold (without any further licence in Mortmain) any lands, buildings, easements or hereditaments of any tenure and any real or personal property of any description whatsoever and to construct, provide, maintain, repair and alter any buildings for all or any of the purposes of the Association, or for any purpose of carrying out the conditions of any trust affecting such

buildings, but provided as regards any lands, tenements and hereditaments within Great Britain or Northern Ireland that the whole thereof shall not exceed the annual value of ten thousand pounds (to be determined according to the value thereof at the time when the same are respectively acquired) and so also that all lands, tenements or hereditaments devised or bequeathed to or for the benefit of the Association by any will or codicil or made over to or for the benefit of the Association by way of gift or any means may be accepted and held by the Association but only upon the terms that if and so far as the holding of the same premises may cause the Association to exceed such limit as aforesaid such premises shall be sold within one year from the date when the Association shall have become entitled thereto in possession. And We do hereby also for Us, Our Heirs and Successors, give and grant Our licence to any person or persons and any body politic or corporate, to assure in perpetuity, or to demise to or for the benefit of the Association any lands, tenements, or hereditaments whatsoever, so as the same do not exceed at any one time the annual value aforesaid.

4. The objects and purposes of the Association shall be as hereinbefore recited as those of the Existing Association and for that purpose the Association shall have power—

(i) To hold meetings of the members of the Association or public meetings at such times and in such places in Our United Kingdom or in Our Dominions, Colonies or Dependencies or elsewhere as the General Committee of the Association shall determine for the reading, hearing and discussing of scientific lectures or communications, and to hold or promote exhibitions of instruments, specimens and things and to promote intercourse between persons concerned or connected with Science.

(ii) To compile, print, publish, lend, sell or distribute reports and proceedings of the Association.

(iii) To enter into any arrangements with any Department of Our Imperial Government or of the Government of any part of Our Dominions or with any local or Municipal Authority or any Corporation, Company, Society,

Association, body or persons whether incorporated or not whose objects are similar to any objects of the Association for the furtherance of those objects.

(iv) To make grants of money or otherwise financially assist any scientific research or object approved by the General Committee or the Council of the Association as within the scope of the objects of the Association.

(v) To accept and take by way of gift and absorb upon any terms approved by the General Committee and the Council the undertaking and assets of any Society or body whether incorporated or not carrying on work similar to any work for the time being carried on by the Association and to undertake and add to the expressed objects of the Association the objects of any other such Society or body.

(vi) To receive and accept donations, endowments, and gifts of money, lands, hereditaments, stocks, funds, shares, securities and any other property and assets whatsoever and either subject or not subject to any special trusts or conditions but so that any powers conferred by this paragraph shall be subject to the proviso contained in Article 3 of this Our Charter, and to improve, manage, develop, sell, exchange, lease, let or otherwise dispose of or mortgage or otherwise charge or deal with or turn to account all or any property of the Association, provided that no disposition of any real property situated in Great Britain or Northern Ireland shall be made without such consent or approval (if any) as may be by law required therefor.

(vii) To undertake, execute, and perform any trusts or conditions affecting any real or personal property of any description acquired by the Association.

(viii) To do all such other acts and things as are or may be deemed incidental or conducive to the attainment of all or any of the purposes of the Association or the exercise of all or any of its said powers.

5. Inasmuch as We have heretofore been Patron of the Existing Association We do hereby reserve to Ourselves to be the First Patron of the Association after the granting of this Our Charter.

6. There shall be a General Committee of the Association being the governing body thereof and exercising such powers and consisting of such members with such qualifications as the Statutes of the Association shall direct. The first General Committee of the Association shall be the General Committee of the existing Association.

7. There shall be a Council of the Association elected by the General Committee, being the executive body of the Association and exercising such powers and consisting of such number of members, to be elected and to hold office for such period, as the Statutes of the Association shall direct. The first Council of the Association shall be the Council of the existing Association.

8. Of the Members of the said General Committee and Council of the Association one shall be the President of the Association, one shall be the General Treasurer thereof, and two or more shall be the General Secretaries thereof. And the said Officers shall be elected by the General Committee in such manner, hold office on such terms, and exercise such powers as the Statutes of the Association shall direct. And the Association shall have such other Officers and Servants as the Council of the Association may from time to time appoint.

9. The terms and conditions of membership of the Association shall be such as the Statutes of the Association shall direct.

10. The affairs of the Association shall be managed and regulated in accordance with the Statutes hereunto scheduled. Any of the Statutes may from time to time be altered, added to or repealed in manner provided by the Statutes and any new Statutes may from time to time be made in the like manner. Provided that no new Statute and no alteration of or addition to any of the Statutes shall have any force or effect if it be repugnant to any of the provisions of this Our Charter or to the Laws of Our Realm and that no such new Statute, alteration, addition or repeal shall take effect until the same has been submitted to and approved by the Lords

of Our Privy Council, of which approval the certificate of the Clerk of Our Privy Council shall be sufficient evidence.

11. The income and property of the Association whencesoever derived shall be applied solely towards the promotion of the objects of the Association hereinbefore expressed or undertaken in addition thereto, and no portion of the said income and property shall be paid or transferred by way of dividend, bonus or otherwise howsoever by way of profit to the members of the Association or any of them, except in the case of and as a salaried Officer of the Association, and provided that nothing in this Article shall prevent the exercise of the powers granted to the Association under Article 4 (iv) of this Our Charter. And the debts and liabilities of the Association shall at all times be discharged by the Association, provided that the liability of the members thereof shall not at any time exceed the amount of the annual subscription and other sums (if any) due from the said members.

12. The Association shall have power through its General Treasurer to invest all moneys and funds of the Association which are not immediately required to be expended for the purposes thereof and which the Council think proper to be invested in such investments as may be authorised by the law for the time being in force for the investment of trust funds, or to deposit the same with any bank, and to grant, continue and pay such salaries, wages, pensions, gratuities, superannuation, retiring allowances or other sums in recognition of services (whether rendered before or after the granting of this Our Charter) as may from time to time be sanctioned by the Council.

13. And We do hereby further declare that if and when the Association shall cease to be an Association for the purposes aforesaid and the affairs thereof shall have been completely wound up and its debts and obligations fully discharged this Our Charter shall be absolutely void, but that if on the winding up or dissolution of the Association there shall remain, after the satisfaction of all its debts,

liabilities and obligations, any property whatsoever, the sum shall not be paid to or distributed among the members of the Association or any of them, but shall (subject to any special trusts affecting the same) be given and transferred to some other society or societies having objects similar to the objects of the Association to be determined by the General Committee at or before the time of dissolution or in default thereof by a Judge of the Chancery Division of Our High Court of Justice.

14. The Council of the Association shall provide for the safe custody of the Common Seal thereof which shall never be used except by the authority of the Council previously given and in the presence of two members of the Council who shall sign every instrument to which the Seal is affixed.

15. And We do hereby for Us, Our Heirs and Successors, Grant and Declare that these Our Letters Patent or the enrolment or exemplification thereof shall be in all things good, firm, valid and effectual according to the true intent and meaning of the same and shall be taken, construed and adjudged in all Our Courts or elsewhere in the most favourable and beneficial sense and for the best advantage of the Association, any mis-recital, non-recital, omission, defect, imperfection, matter or thing whatsoever notwithstanding.

In Witness whereof We have caused these Our Letters to be made Patent.

Witness Ourself at Westminster the twenty-first day of April in the year of Our Lord One thousand nine hundred and twenty-eight and in the eighteenth year of Our Reign.

By Warrant under The King's Sign Manual.

SCHUSTER

SEAL

THE SCHEDULE

British Association for the Advancement of Science

STATUTES

Chapter I.

Objects and Constitution.

Objects.

1. The objects of the British Association for the Advancement of Science are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate Science in different parts of the British Empire with one another and with foreign philosophers; to obtain more general attention for the objects of Science and the removal of any disadvantages of a public kind which impede its progress.

The Association contemplates no invasion of the ground occupied by other Institutions.

Constitution.

2. The Association shall consist of Members and Honorary Corresponding Members.

The governing body of the Association shall be a General Committee, constituted as hereinafter set forth; and its affairs shall be directed by a Council and conducted by General Officers appointed by that Committee.

Annual Meetings.

3. The Association shall meet annually, for one week or longer, and at such other times as the General Committee may appoint. The place of each Annual Meeting shall be determined by the General Committee not less than two years in advance; and the arrangements for these meetings shall be entrusted to the Officers of the Association.

Chapter II.

The General Committee.

Constitution.

1. The General Committee shall be constituted of the following persons:—

(i) *Permanent Members*—

(*a*) Past and present Members of the Council, past and present Presidents of the Sections, and Recorders of Sections on retirement.

(*b*) Members who, by the publication of works or papers, have furthered the advancement of knowledge in any of those departments which are assigned to the Sections of the Association.

(ii) *Temporary Members*—

(*a*) Vice-Presidents and Secretaries of the Sections.

(*b*) Honorary Corresponding Members, foreign representatives, and other persons specially invited or nominated by the Council or General Officers.

(*c*) Delegates nominated by the Affiliated Societies.

(*d*) Delegates—not exceeding altogether three in number—from Scientific Institutions established at the place of meeting.

2. The decision of the Council on the qualifications and claims of any Member of the Association to be placed on the General Committee shall be final. Admission.

3. The General Committee shall meet twice at least during every Annual Meeting. In the interval between two Annual Meetings, it shall be competent for the Council at any time to summon a meeting of the General Committee. Meetings.

4. The General Committee shall— Functions.

(i) Receive and consider the Report of the Council.

(ii) Elect a Committee of Recommendations.

(iii) Receive and consider the Report of the Committee of Recommendations.

(iv) Determine the place of the Annual Meeting not less than two years in advance.

(v) Determine the date of the next Annual Meeting.

(vi) Elect the President and Vice-Presidents, Local Treasurer, and Local Secretaries for the next Annual Meeting.

(vii) Elect Ordinary Members of Council.

(viii) Appoint General Officers.

(ix) Appoint Auditors.

(x) Elect the Officers of the Conference of Delegates.

(xi) Receive any notice of motion for the next Annual Meeting.

Chapter III.

Committee of Recommendations.

1. The *ex officio* Members of the Committee of Recommendations are the President and Vice-Presidents of the Association, the President of each Section at the Annual Meeting, the President of the Conference of Delegates, the Constitution.

General Secretaries, the General Treasurer, and the Presidents of the Association in former years.

An Ordinary Member of the Committee for each Section shall be nominated by the Committee of that Section.

If the President of a Section be unable to attend a meeting of the Committee of Recommendations, the Sectional Committee may appoint a Vice-President, or some other member of the Committee, to attend in his place, due notice of such appointment being sent to the Secretary of the Association.

Functions. 2. Every recommendation made under Chapter IV. and every resolution on a scientific subject, which may be submitted to the Association by any Sectional Committee, or by the Conference of Delegates, or otherwise than by the Council of the Association, shall be submitted to the Committee of Recommendations. If the Committee of Recommendations approve such recommendation, they shall transmit it to the General Committee; and no recommendation shall be considered by the General Committee that is not so transmitted.

Every recommendation adopted by the General Committee shall, if it involve action on the part of the Association, be transmitted to the Council; and the Council shall take such action as may be needful to give effect to it, and shall report to the General Committee not later than the next Annual Meeting.

Every proposal for establishing a new Section, for altering the title of a Section, or for any other change in the constitutional forms or statutes of the Association, shall be referred to the Committee of Recommendations for their consideration and report.

Chapter IV.

Research Committees.

Procedure. 1. Every proposal for special research, or for a grant of money in aid of special research, which is made in any Section, shall be considered by the Committee of that Section; and, if such proposal be approved, it shall be referred to the Committee of Recommendations.

In consequence of any such proposal, a Sectional Committee may recommend the appointment of a Research Committee to conduct research or administer a grant in aid of research, and in any case to report thereon to the Association; and the Committee of Recommendations may include such recommendation in their Report to the General Committee.

2. Every appointment of a Research Committee shall be proposed at a meeting of the Sectional Committee and adopted at a subsequent meeting. The Sectional Committee shall settle the terms of reference and suitable Members to serve on it, which must be as small as is consistent with its efficient working; and shall nominate a Chairman and a Secretary. Research Committees shall have power to add to their numbers. Constitution.

3. The Sectional Committee shall state in their recommendation whether a grant of money be desired for the purposes of any Research Committee, and shall estimate the amount required. Proposals by Sectional Committees.

4. Research Committees are appointed for one year only. If the work of a Research Committee cannot be completed in that year, application may be made through a Sectional Committee at the next Annual Meeting for reappointment, with or without a grant—or a further grant—of money. Tenure.

5. Every Research Committee shall present a Report, whether interim or final, at the Annual Meeting next after that at which it was appointed or reappointed, and may in the meantime present a Report through a Sectional Organising Committee to the Council. Interim Reports, whether intended for publication or not, must be submitted in writing. Each Sectional Committee shall ascertain whether a Report has been made by each Research Committee appointed on their recommendation, and shall report to the Committee of Recommendations. Reports.

6. In each Research Committee to which a grant of money has been made, the Chairman is the only person entitled to call on the General Treasurer for such portion of the sum granted as from time to time may be required. GRANTS. (*a*) Drawn by Chairman.

Grants of money sanctioned at the Annual Meeting expire at the close of the financial year of the Association following, to wit, on June 30, or on such other date as the General Committee may appoint. The General Treasurer is not authorised, after that date, to allow any claims on account of such grants. (*b*) Expire at close of financial year.

A Research Committee, whether or not in receipt of a grant, shall not raise money, in the name or under the auspices of the Association, without special permission from the General Committee. (*c*) *Caveat.*

CHAPTER V.

The Council.

1. The Council shall consist of *ex officio* Members and of Ordinary Members elected annually by the General Committee. Constitution.

(i) The *ex officio* Members are—Past Presidents of the Association, the President for the year, the President and Vice-Presidents for the ensuing Annual Meeting, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the Annual Meetings immediately past and ensuing.

(ii) The Ordinary Members shall not exceed twenty-five in number. Of these, not more than twenty shall have served on the Council as Ordinary Members in the previous year.

Functions.

2. The Council shall have authority to act, in the name and on behalf of the Association, in all matters which do not conflict with the functions of the General Committee.

In the interval between two Annual Meetings, the Council shall manage the affairs of the Association and may fill up vacancies among the General and other Officers, until the next Annual Meeting.

The Council shall hold such meetings as they may think fit, and shall in any case meet on the first day of the Annual Meeting, in order to complete and adopt the Annual Report, and to consider other matters to be brought before the General Committee.

Elections.

The Council shall nominate for election by the General Committee, at each Annual Meeting, a President and General Officers of the Association.

The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as they may from time to time determine.

3. Election to the Council shall take place at the same time as that of the Officers of the Association.

(i) At each Annual Election, the following Ordinary Members of the Council shall be ineligible for re-election in the ensuing year:

(*a*) Three of the Members who have served for the longest consecutive period, and

(*b*) Two of the Members who, being resident in or near London, have attended the least number of meetings during the past year.

Nevertheless, it shall be competent for the Council, by an unanimous vote, to reverse the proportion in the order of retirement above set forth.

(ii) The Council shall submit to the General Committee, in their Annual Report, the names of twenty-three Members of the Association whom they recommend for election as Members of Council.

(iii) Two Members shall be elected by the General Committee, without nomination by the Council; and this election shall be at the same meeting as that at which the election of the other Members of the Council takes place.

Any member of the General Committee may propose another member thereof for election as one of these two Members of Council, and, if only two are so proposed, they shall be declared elected; but, if more than two are so proposed, the election shall be by show of hands, unless five Members at least, present at the meeting of the General Committee, require it to be by ballot.

Chapter VI.

The President, General Officers, and Staff.

1. The President shall assume office on the first day of the Annual Meeting, when he shall deliver a Presidential Address. He shall resign office at the next Annual Meeting, when he inducts his successor into the Chair. The President.

The President shall preside at all meetings of the Association or of its Council and Committees which he attends in his capacity as President.

2. The General Officers of the Association are the General Treasurer and the General Secretaries. General Officers.

It shall be competent for the General Officers to act, in the name of the Association, in any matter of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

3. The General Treasurer shall be responsible to the General Committee and the Council for the financial affairs of the Association. The General Treasurer.

4. The General Secretaries shall control the general organisation and administration, and shall be responsible to the General Committee and the Council for conducting the correspondence and for the general routine of the work of the Association, excepting that which relates to Finance. The General Secretaries.

5. The Secretary of the Association shall hold office during the pleasure of the Council. He shall act under the direction of the General Secretaries, and in their absence shall represent them. He shall also act on the directions which may The Secretary.

be given him by the General Treasurer in that part of his duties which relates to the finances of the Association.

The Secretary shall be charged, subject as aforesaid: (i) with the general organising and editorial work, and with the administrative business of the Association; (ii) with the control and direction of the Office and of all persons therein employed; and (iii) with the execution of Standing Orders or of the directions given him by the General Officers and Council. He shall act as Secretary, and take Minutes, at the meetings of the Council, and at all meetings of Committees of the Council, of the Committee of Recommendations, and of the General Committee.

Chapter VII.

Finance.

Financial Statements.

1. The General Treasurer, or his representative, shall receive and acknowledge all sums of money paid to the Association. He shall submit, at each meeting of the Council, an interim statement of his Account; and shall prepare and submit to the General Committee, at the Annual Meeting, a balance-sheet of the funds of the Association completed to the close of the financial year.

Audit.

2. The Accounts of the Association shall be audited, annually, by Auditors appointed by the General Committee.

Expenditure.

3. The General Treasurer shall make all ordinary payments authorised by the General Committee or by the Council.

Investments.

4. The General Treasurer is empowered to draw on the account of the Association, and, with the authority of the Council, to invest on behalf of the Association part or all of the balance standing at any time to the credit of the Association in the books of the Association's bankers, in such investments as may be authorised for the investment of trust funds.

Cheques.

5. In the event of the General Treasurer being unable, from illness or any other cause, to exercise the functions of his office, the President of the Association for the time being and one of the General Secretaries shall be jointly empowered to sign cheques on behalf of the Association.

Caveat.

6. No gift, bonus, dividend, or division in money shall be made out of the funds of the Association, to or between any of its members.

Chapter VIII.

The Annual Meetings.

1. Local Committees shall be formed to assist the General Officers in making arrangements for the Annual Meeting, and shall have power to add to their number. Local Officers and Committees.

2. The General Committee shall appoint, on the recommendation of the Local Reception or Executive Committee for the ensuing Annual Meeting, a Local Treasurer or Treasurers and two or more Local Secretaries, who shall rank as officers of the Association, and shall consult with the General Officers and the Secretary as to the local arrangements necessary for the conduct of the meeting. The Local Treasurers shall be empowered to enrol Members, and to receive subscriptions.

3. The Local Committees and Sub-Committees shall undertake the local organisation, and shall have power to act in the name of the Association in all matters pertaining to the local arrangements for the Annual Meeting other than the work of the Sections. Functions.

4. The Council, in consultation with the Local Executive Committee of the Association for the Annual Meeting, may provide evening or other lectures during the meeting, to which the public, other than members of the Association, shall be admitted free, and shall appoint lecturers for this purpose, having regard to the scientific and educational needs and interests of the place of meeting and its neighbourhood.

Chapter IX.

The Work of the Sections.

1. The scientific work of the Association shall be transacted under such Sections as shall be constituted from time to time by the General Committee. The Sections.

It shall be competent for any Section, if authorised by the Council for the time being, to form a Sub-Section for the purpose of dealing separately with any group of communications addressed to that Section.

2. There shall be in each Section a President, two or more Vice-Presidents, and two or more Secretaries. They shall be appointed by the Council, for each Annual Meeting in advance, and shall act as the Officers of the Section from the date of their appointment until the appointment of their successors in office for the ensuing Annual Meeting. Sectional Officers.

Of the Secretaries, one shall act as Recorder of the Section, and one shall be resident in the locality where the Annual Meeting is held.

SECTIONAL COMMITTEES.

3. The work of each Section shall be conducted by a Sectional Committee, which shall consist of the following :—

Constitution

(i) The Officers of the Section during their term of office.

(ii) All past Presidents of that Section.

(iii) Such other Members of the Association, present at any Annual Meeting, as the Sectional Committee, thus constituted, may co-opt for the period of the meeting :

Provided always that—

Co-optation.

(*a*) A Sectional Committee may co-opt members, as above set forth, at any time during the Annual Meeting, and shall publish daily a revised list of the members.

Additional Vice-Presidents.

(*b*) A Sectional Committee may, at any time during the Annual Meeting, appoint not more than three persons present at the meeting to be Vice-Presidents of the Section, in addition to those previously appointed by the Council.

EXECUTIVE FUNCTIONS.

4. The chief executive officers of a Section shall be the President and the Recorder. They shall have power to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the Sectional Committee ; and they shall report such action to the Sectional Committee at its next meeting.

Of President

The President (or, in his absence, one of the Vice-Presidents) shall preside at all meetings of the Sectional Committee or of the Section. His ruling shall be absolute on all points of order that may arise.

and of Recorder.

The Recorder shall be responsible for the punctual transmission, to the Secretary of the Association, of the programme of his Section, of the recommendations adopted by the Sectional Committee, of the printed returns, abstracts, reports, or papers appertaining to the proceedings of his Section at the Annual Meeting, and for the correspondence and minutes of the Sectional Committee.

Organising Committee.

5. The Sectional Committee shall nominate, before the close of the Annual Meeting, not more than six members of the Association who, together with the sectional officers and past Presidents of the Section, shall form a Sectional Organising Committee from the close of the Annual Meeting until the conclusion of its meeting on the first day of the ensuing Annual Meeting.

Each Organising Committee shall hold such meetings as are deemed necessary for the organisation of the ensuing Sectional proceedings, and may at any such meeting resolve to present a report to the Council upon any matter of interest to the Section, and shall hold a meeting on the first day of the Annual Meeting: to nominate members of the Sectional Committee, to confirm the Provisional Programme of the Section, and to report to the Sectional Committee.

Sectional Committee.

Each Sectional Committee shall meet daily, unless otherwise determined, during the Annual Meeting: to co-opt members, to complete the arrangements for the next day, and to take into consideration any suggestion for the advancement of Science that may be offered by any member of the Association, or may arise out of the proceedings of the Section.

Papers and Reports.

No paper shall be read in any Section until it has been accepted by the Sectional Committee and entered as accepted on its Minutes.

Recommendations.

It shall be within the competence of the Sectional Committee to review the recommendations adopted at preceding Annual Meetings, as published in the Annual Reports of the Association, and the communications made to the Section at its current meetings, for the purpose of selecting definite objects of research, in the promotion of which individual or concerted action may be usefully employed; and, further, to take into consideration those branches or aspects of knowledge on the state and progress of which reports are required: to make recommendations and nominate individuals or Research Committees to whom the preparation of such reports, or the task of research, may be entrusted, discriminating as to whether, and in what respects, these objects may be usefully advanced by the appropriation of money from the funds of the Association, by reference to local authorities, public institutions, or Departments of His Majesty's Government, or otherwise. The appointment of such Research Committees shall be made in accordance with the provisions of Chapter IV.

No proposal arising out of the proceedings of any Section shall be referred to the Committee of Recommendations unless it shall have received the sanction of the Sectional Committee.

Publication.

6. Papers ordered to be printed *in extenso* shall not be included in the Annual Report, if published elsewhere prior to the issue of the Annual Report in volume form. Reports of Research Committees shall not be published elsewhere than in the Annual Report without the express sanction of the Council.

Copyright.

7. The copyright of addresses and papers ordered by the General Committee to be printed *in extenso* in the Annual

Report shall be vested in the authors; and the copyright of the Reports of Research Committees appointed by the General Committee shall be vested in the Association.

Chapter X.

Admission of Members.

Applications.

1. No technical qualification shall be required on the part of an applicant for admission as a Member of the British Association; but the Council is empowered, in the event of special circumstances arising, to impose suitable conditions and restrictions in this respect.

The Council shall also have power to refuse any application for membership.

Obligations.

Every person admitted as a Member shall conform to the Statutes and Regulations of the Association, and for any infringement thereof shall be liable to exclusion by the Council, who have also authority, if they think it necessary, to withhold from any person the privilege of attending any Annual Meeting or to cancel a ticket of admission already issued.

Expulsion.

If it shall appear to the Council that it is not desirable that a person shall continue to be a Member of the Association, the Council shall direct the General Secretaries to ascertain whether that person is willing to resign his membership.

If that person do not, within a time to be fixed by the Council, either resign or appeal in writing to the General Committee, the Council may declare such person to be no longer a Member. Upon the appeal, the General Committee may make the like declaration by a majority of two-thirds of those present and voting.

It shall be competent for the General Officers to act, in the name of the Council, on any occasion of urgency which cannot be brought under the consideration of the Council; and they shall report such action to the Council at the next meeting.

Conditions and Privileges of Membership.

2. All Members, except as hereafter provided, are eligible to any office in the Association.

(i) Every *Life Member* hereafter admitted shall pay, on admission, the sum of Fifteen Pounds.

(ii) Every *Annual Member* shall pay, on admission, the sum of One Pound, and in any subsequent year the sum of One Pound.

(iii) Persons not exceeding twenty-three years of age, being students of universities or of any educational

institution recognised by the Local Executive Committee or the General Officers of the Association, may obtain 'Students' Tickets' for the Annual Meeting on payment of 10*s*. Holders of such tickets shall not be entitled to any privilege beyond attendance at the Annual Meeting.

(iv) Transferable tickets, admitting one person to any meeting or function during the Annual Meeting, shall be issued at the price of £1 5*s*. Holders of such tickets shall not be entitled to any privilege beyond such admission. No other tickets issued by the Association shall be transferable.

3. Honorary Corresponding Members may be appointed by the General Committee, on the nomination of the Council. They shall be entitled to all the privileges of Membership. Honorary Corresponding Members.

4. Subscriptions are payable at or before the Annual Meeting. Annual Members not attending the meeting may make payment at any time before the close of the financial year of the Association. Annual Subscriptions.

(i) Every Life Member, whether admitted before or after the adoption of these Rules, shall be entitled to receive *gratis*, on demand, the Annual Reports of the Association issued in and after the year of admission. The Annual Report.

(ii) Annual Members attending an Annual Meeting shall be entitled to obtain the Report of that Meeting for an additional payment of 10*s*. made before or during the Annual Meeting, or of 12*s*. 6*d*. made after the Annual Meeting within a period not extending beyond the close of the financial year of the Association.

Provided that Annual Members who have paid the annual subscription of £1 without intermission from a date anterior to September 14, 1919, and continue to do so, shall be entitled to receive the Annual Report, on demand, without further payment.

(iii) Annual Members who pay the annual subscription of £1, but do not attend the Annual Meeting, shall be entitled to receive the Annual Report, on demand, without further payment.

(iv) Holders of Students' or transferable tickets shall not be entitled to receive the Annual Report on the terms above stated.

(v) Subject to any statutory rights, or other considerations in the discretion of the Council, libraries and

institutions shall be entitled to purchase the Annual Volume at a subscription rate of 12*s.* 6*d.* per annum.

(vi) The publication price of the Annual Report shall be determined from time to time by the General Committee.

(vii) Volumes not claimed within two years of the date of publication may be issued only by direction of the Council.

Chapter XI.

Corresponding Societies: Conference of Delegates.

Affiliated Societies.

1. Corresponding Societies shall be constituted as follows:

(i) Any Society which undertakes local scientific investigation and publishes the results may become a Society *affiliated* to the British Association.

Each Affiliated Society shall have the right to appoint a Delegate to attend the meetings of the Conference of Delegates. He shall be or become a Member of the Association, and shall be *ex officio* a Member of the General Committee.

Associated Societies.

(ii) Any Society formed for the purpose of encouraging the study of Science, which has existed for three years and numbers not fewer than fifty members, may become a Society *associated* with the British Association.

Each Associated Society shall have the right to appoint a Delegate to attend the Annual Conference. Such Delegates, provided that they are or become Members of the British Association, shall have all the rights of Delegates appointed by the Affiliated Societies, except that of membership of the General Committee.

Corresponding Societies Committee.

2. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee, for the purpose of keeping themselves generally informed of the work of the Corresponding Societies. This Committee shall make an Annual Report to the Council, and shall suggest such additions or changes in the list of Corresponding Societies as they may consider desirable.

Conference of Delegates.

3. The Delegates of Corresponding Societies, being Members of the Association, shall constitute a Conference, of

which the President and other officers shall be appointed by the Council, and which shall hold meetings under such conditions as the General Committee shall determine.

Chapter XII.

Amendments and New Statutes.

Any alterations in the Statutes, and any amendments or new Statutes that may be proposed by the Council or individual Members, shall be notified to the General Committee, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at a further meeting of the General Committee.

REGULATIONS.

Admission to Membership of the General Committee.

1. Claims for admission to permanent membership of the General Committee must be lodged with the Secretary of the Association at least one month before the Annual Meeting, either by claimants themselves or by Recorders on behalf of sectional Organising Committees desiring to make recommendations for admission.

2. Claims for admission as a Temporary Member of the General Committee may be sent to the Secretary at any time before or during the Annual Meeting.

Committee of Recommendations.

3. All proposals sanctioned by a Sectional Committee shall be forwarded by the Recorder to the Secretary of the Association, who shall give previous notice of the hours at or before which such proposals must be received by him, for presentation to the Committee of Recommendations.

4. The Committee of Recommendations shall hold at least one meeting, and shall submit a report to the General Committee at the final meeting thereof, during the Annual Meeting of the Association.

Research Committees.

5. Research Committees shall be composed of Members of the Association, provided that it shall be competent for the General Committee to appoint, or for a Research Committee to co-opt, as an assessor or consultative member, any person, not being a Member of the Association, whose assistance may be regarded as of special importance to the research undertaken.

6. The Chairman of a Research Committee must, before the Annual Meeting next following the appointment of the Research Committee, forward to the General Treasurer a statement of the sums that have been received and expended, together with vouchers. The Chairman must then return the balance of the grant, if any, which remains unexpended; provided that a Research Committee may, in the first year of its appointment only, apply for leave to retain an unexpended balance when or before its Report is presented, due reason being given for such application.

When application is made for a Committee to be reappointed, and to retain the balance of a former grant, and also to receive a further grant, the amount of such further grant is to be estimated as being sufficient, together with the balance proposed to be retained, to make up the amount desired.

7. If any payment of travelling expenses be contemplated out of a grant to a Research Committee, the amount to be so allocated shall be stated in the application for such grant, and such payment shall be expressly recommended by the Committee of Recommendations and approved by the General Committee (or in the event of subsequent emergency, by the Council), and shall be confined to railway or other fares.

8. Members and Committees entrusted with sums of money for collecting specimens of any description shall include in their Reports particulars thereof, and shall reserve the specimens thus obtained for disposal, as the Council may direct.

Committees are required to furnish a list of any apparatus which may have been purchased out of a grant made by the Association, and to state whether the apparatus is likely to be useful for continuing the research in question or for other specific purposes.

All instruments, drawings, papers, and other property of the Association, when not in actual use by a Committee, shall be deposited at the Office of the Association.

Nomination of President of the Association by Council.

9. Suggestions for the Presidency shall be considered by the Council at the meeting in February, and the names selected shall be issued with the summonses to the Council meeting in March, when the nomination shall be made from the names on the list.

Assistant to the General Treasurer.

10. The General Treasurer may depute the Secretary or other salaried officer to carry on under his direction the routine work of the duties of his office. Such officer shall be charged with the issue of membership tickets and such other work as may be delegated to him.

Travelling Expenses, etc.

11. The General Treasurer shall be authorised, subject to approval, and within limitations defined, by the Council, to defray travelling and other expenses of officers as follows:—

(i) Railway fares and postages incurred by the President and General Officers in connection with the Annual Meeting, the meetings of the Council, and other meetings involved by the discharge of their official duties.

(ii) Railway fares and subsistence expenses incurred by members of the Staff in connection with attendance at the Annual Meeting and otherwise in the discharge of their duties.

(iii) Railway fares incurred by Recorders and Secretaries of Sections in connection with the Annual Meeting, and with the preceding joint meeting of the Organising Sectional Committees.

(iv) Postages and essential clerical expenses incurred by the Recorders (or their sectional secretaries on their behalf) in the discharging of their duties, provided that no claim exceeding £5 under this heading by any Recorder in any one year shall be allowed without the express sanction of the Council.

It shall be competent for the Council, if they think desirable, to authorise payments in respect of travelling expenses to Members appointed by them to represent the Association at meetings of other bodies, for which formal invitation has been received.

The Sections.

12. The Section Rooms and the approaches thereto shall not be used without sanction for any notices, exhibitions, or other purposes than those of the Association.

13. The Organising Committee of any Section may elect as a member of the Sectional Committee for its first meeting any Member of the Association who has intimated his intention of being present at the Annual Meeting.

The Sectional Committee may elect to the committee any Member of the Association in attendance at the Annual Meeting.

14. Any report or paper read in any one Section may be read also in any other Section.

15. No paper or abstract of a paper shall be printed in the Annual Report of the Association unless the manuscript has been received by the Recorder of the Section before the close of the Annual Meeting.

Membership.

16. It shall be competent for the Council to nominate, and for the General Committee to elect, any person to honorary membership for eminent services to the Association.

17. It shall be competent for the General Treasurer, or the Secretary of the Association duly authorised by him, to issue complimentary membership tickets for any one Annual Meeting to :—

(i) Honorary Corresponding Members attending the Meeting, and distinguished men of science from foreign countries or from the British Dominions overseas, invited by the Council to attend the Meeting as guests, on the nomination of the Organising Sectional Committees or otherwise.

(ii) The local secretaries, local treasurers, and local sectional secretaries for the Meeting, and any other persons resident in the locality of the Meeting whose services in connection with the local organisation thereof shall, in the opinion of the local secretaries after consultation with the Secretary, entitle them to honorary membership for the Meeting.

The General Treasurer shall bring to the notice of the Council, for consideration and action if desirable, any other proposal for the issue of complimentary tickets, save as provided in Regulation 17 below.

18. The Council may before each Annual Meeting (other than meetings overseas), with the assent of the local executive committee, invite Universities and University Colleges in Great Britain to nominate each one or more students in science, not above the standing of B.Sc., as "British Association Exhibitioners."

Such Exhibitioners shall receive complimentary students' tickets for the Annual Meeting and their travelling expenses (fares) incurred in attending the Meeting shall be met or assisted out of the funds of the Association in accordance with a scale determined by the Council, and the Council shall consult with the local executive committee as to the defrayment of their subsistence expenses during the Meeting. The Council shall also have power to enter into arrangements with university and other authorities respecting the attendance of other selected students whose expenses shall not fall upon the funds of the Association.

19. It shall be competent for the Organising Sectional Committees to invite or accept communications at any Annual Meeting from persons not already Members of the Association, and the attention of such persons (if not entitled to complimentary tickets) shall be called to the terms of membership; but if any such person shall be unable to attend the Meeting except on the day on which he is to deliver his communication, the Secretary shall have power to issue to him a card of admission to his Section for that day.

20. It shall be competent for the General Treasurer, if desired by the local executive committee for any Annual Meeting, to enter into an arrangement with such committee under which each subscriber of five guineas or other agreed sum or upward to any fund raised to defray local expenses of the Meeting shall receive a membership ticket for that Meeting, the sum of fifteen shillings instead of one pound being payable from the local fund to the Association for each such ticket; and it shall be competent for the Council to consider and adopt any proposal by a local executive committee for a special fee for such tickets for local members.

21. An Annual Member subscribing in any year shall receive notices of the Annual Meetings in the four succeeding years; but if during that period he shall not have resumed membership his name shall be removed from the current membership list to a suspense list.

Annual Members being Members of the General Committee shall in like manner be entitled to receive notices of any special meetings or other business of the General Committee during the period of four years after the payment of their last subscriptions; but their names shall thereafter be transferred to a suspense list; provided that if any member whose

name has been so transferred shall subsequently resume his subscription, he shall continue in membership of the General Committee.

22. It shall be competent for the Council, on the occasion of an Annual Meeting overseas, to require from members proposing to attend such meeting an expression of their intention to participate in the scientific transactions of the meeting.

Printed Matter.

23. Presidents shall be entitled to receive one hundred copies of their addresses without charge, and additional copies at the cost of reproduction. One hundred copies of reports of Research Committees printed in advance of the Annual Meeting shall be provided for use thereat; additional copies at the discretion of the General Officers. Authors of communications ordered to be printed *in extenso* in the Annual Report shall receive twenty-five copies of their communications without charge, and additional copies at the cost of reproduction.

Corresponding Societies: Conference of Delegates.

24. Application may be made by any Society to be placed on the list of Corresponding Societies. Such application must be addressed to the Secretary of the Association on or before the 1st of June preceding the Annual Meeting at which it is intended it should be considered, and must, in the case of Societies desiring to be affiliated, be accompanied by specimens of the publications of the results of local scientific investigations recently undertaken by the Society.

25. Each Corresponding Society shall forward every year on or before June 1, if requested to do so by the Secretary of the Association, such particulars in regard to the Society as may be required for the information of the Corresponding Societies Committee.

26. The Conference of Delegates shall be summoned by the Secretary to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member to take part in the discussions.

27. The Conference of Delegates shall be empowered to submit Resolutions to the Committee of Recommendations for their consideration, and for report to the General Committee.

28. The Sectional Committees of the Association shall be requested to transmit to the Secretary for reference to the Conference of Delegates, copies of any recommendations to be made to the General Committee bearing upon matters in which the co-operation of Corresponding Societies is desirable. It shall be competent for the Conference of Delegates to invite the authors of such recommendations to attend the meetings of the

Conference in order to give verbal explanations of their objects and of the precise way in which they desire these to be carried into effect.

29. It shall be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they may be able to bring such recommendations adequately before their respective Societies.

30. The Conference may also discuss propositions regarding the promotion of more systematic observation and plans of operation, and of greater uniformity in the method of publishing results.

Amendments to Regulations.

31. Any alterations in the Regulations, and any amendments or new Regulations that may be proposed by the Council or individual Members, shall be notified to the General Committee at its first meeting during the Annual Meeting, and referred forthwith to the Committee of Recommendations; and, on the report of that Committee, shall be submitted for approval at the last meeting of the General Committee. Provided that the Council may bring into operation in the interval between Annual Meetings any amendment within the scope of its functions, and shall report the same to the General Committee at the ensuing Annual Meeting.

British Association for the Advancement of Science.

OFFICERS & COUNCIL, 1928-29.

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HIS MAJESTY THE KING.

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The Rt. Hon. the Earl of Glasgow, D.S.O.
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The Prime Minister of the Union of South Africa.
The Minister for Education.
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The Administrator of the Cape Province.
The Administrator of the Natal Province.
The Administrator of the Orange Free State.
The Administrator of the Transvaal Province.
The Vice-Chancellor of the University of South Africa.
The Vice-Chancellor of the University of Cape Town.
The Vice-Chancellor of the University of Stellenbosch.
The Vice-Chancellor of the University of the Witwatersrand.
The Mayor of Johannesburg.
The Mayor of Cape Town.
The Mayor of Pretoria.
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Prof. J. A. Wilkinson, Chairman of the General Committee of the South African Association.
The President of the Associated Scientific and Technical Societies of South Africa.
Alpheus F. Williams, General Manager, De Beers Consolidated Mines, Ltd.
Acting Chief Justice Jacob de Villiers.

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Sir Josiah Stamp, G.B.E., D.Sc.

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SECRETARY.

O. J. R. Howarth, O.B.E., M.A., Burlington House, London, W. 1.

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CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

President.—Dr. VAUGHAN CORNISH.

TABLE OF

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S. ...	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S....	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne...	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S. ...	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S. ...	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S. ...	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres.R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D., F.R.S....	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S....	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S. ...	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne...	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S. ...	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne...	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S. ...	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S. ...	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec.R.S....	296	20

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

[*Continued on p.* xl.

ANNUAL MEETINGS.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899

‡ Including Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting

[*Continued on p.* xli.

Table of

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S. ...	267	13
1901, Sept. 11	Glasgow..................	Prof. A. W. Rücker, D.Sc., Sec.R.S. ...	310	37
1902, Sept. 10	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17......	Cambridge...............	Rt. Hon. A. J. Balfour, M.P., F.R.S.	419	32
1905, Aug. 15......	South Africa	Prof. G. H. Darwin, LL.D., F.R.S. ...	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25......	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31	Sheffield.................	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S................	288	14
1913, Sept. 10	Birmingham	Sir Oliver J. Lodge, F.R.S............ ...	376	40
1914, July-Sept....	Australia	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S.	242	19
1916, Sept. 5	Newcastle-on-Tyne...	Sir Arthur Evans, F.R.S.	164	12
1917	(No Meeting)		—	—
1918	(No Meeting)		—	—
1919, Sept. 9	Bournemouth	Hon. Sir C. Parsons, K.C.B., F.R.S....	235	47
1920, Aug. 24......	Cardiff	Prof. W. A. Herdman, C.B.E., F.R.S.	288	11
1921, Sept. 7	Edinburgh	Sir T. E. Thorpe, C.B., F.R.S.	336	9
1922, Sept. 6	Hull	Sir C. S. Sherrington, G.B.E., Pres. R.S.	228	13
1923, Sept. 12	Liverpool	Sir Ernest Rutherford, F.R.S.	326	12
1924, Aug. 6	Toronto	Sir David Bruce, K.C.B., F.R.S.......	119	7
1925, Aug. 26	Southampton	Prof. Horace Lamb, F.R.S.	280	8
1926, Aug. 4	Oxford	H.R.H. The Prince of Wales, K.G., F.R.S.	358	9
1927, Aug. 31	Leeds	Sir Arthur Keith, F.R.S.	249	9
1928, Sept. 5	Glasgow..................	Sir William Bragg, K.B E., F.R.S. ...	260	10

[1] Including 848 Members of the South African Association.
[2] Including 137 Members of the American Association.
[3] Special arrangements were made for Members and Associates joining locally in Australia, see Report, 1914, p. 686. The numbers include 80 Members who joined in order to attend the Meeting of L'Association Française at Le Havre.
[4] Including Students' Tickets, 10*s*.
[5] Including Exhibitioners granted tickets without charge.

Annual Meetings—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
297	45	801	482	9	1915	£1801 0	£1072 10 0	1900
374	131	794	246	20	1912	2046 0	920 9 11	1901
314	86	647	305	6	1620	1644 0	947 0 0	1902
319	90	688	365	21	1754	1762 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0	887 18 11	1904
937[1]	411	430	181	16	2130	2422 0	928 2 2	1905
356	93	817	352	22	1972	1811 0	882 0 9	1906
339	61	659	251	42	1647	1561 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0	1157 18 8	1908
290[2]	162	789	90	7	1468	1623 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0	963 17 0	1910
349	61	414	81	31	1241	1176 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0	978 17 1	1913
139	4160[3]	539[3]	—	21	5044[3]	4873 0	1861 16 4[6]	1914
287	116	628[4]	141	8	1441	1406 0	1569 2 8	1915
250	76	251[4]	73	—	826	821 0	985 18 10	1916
—	—	—	—	—	—	—	677 17 2	1917
—	—	—	—	—	—	—	326 13 3	1918
254	102	688[4]	153	3	1482	1736 0	410 0 0	1919

Old Annual Regular Members	Annual Members: Meeting and Report	Annual Members: Meeting only	Transferable Tickets	Students' Tickets	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
136	192	571	42	120	20	1380	1272 10	1251 13 0[8]	1920
133	410	1394	121	343	22	2768	2599 15	518 1 10	1921
90	294	757	89	235[5]	24	1730	1699 5	772 0 7	1922
					Complimentary.				
123	380	1434	163	550	308[7]	3296	2735 15	777 18 6[9]	1923
37	520	1866	41	89	139	2818	3165 19[10]	1197 5 9	1924
97	264	878	62	119	74	1782	1630 5	1231 0 0	1925
101	453	2338	169	225	69	3722	3542 0	917 1 6	1926
84	334	1487	82	264	161	2670	2414 5	761 10 0	1927
76	554	1835	64	201	74	3074	3072 10	1259 10 0	1928

[6] Including grants from the Caird Fund in this and subsequent years.
[7] Including Foreign Guests, Exhibitioners, and others.
[8] The Bournemouth Fund for Research, initiated by Sir C. Parsons, enabled grants on account of scientific purposes to be maintained.
[9] Including grants from the Caird Gift for research in radioactivity in this and subsequent years to 1926.
[10] Subscriptions paid in Canada were $5 for Meeting only and others pro rata; there was some gain on exchange.

REPORT OF THE COUNCIL, 1927-28.

I. The Council desires to congratulate the General Committee upon the success of the petition to H.M. the King in Council, made on the Committee's instruction by the President and General Officers, for the grant of a Royal Charter of Incorporation to the Association. The grant was approved on March 22, and the Charter was received on April 27.

The Council conveyed to Mr. A. A. Campbell Swinton its warm thanks for his generous donation of £200, covering the costs of the Charter and expenses incidental to its acquisition.

The Council has caused the Association's securities, hitherto in the hands of Trustees, namely Major P. A. MacMahon, Sir Arthur Evans, and the Hon. Sir Charles Parsons, to be transferred to the Association itself. The Council commends the generous services of the Trustees to the General Committee for an expression of their appreciation.

The Council has had under consideration those of the former Rules of the Association which have not been embodied in the Statutes appended as a schedule to the Charter, has amended and added to them, and submits them to the General Committee and the Committee of Recommendations for consideration and adoption as Regulations supplementary to the Statutes.

II. The Council tendered its grateful thanks to H.R.H. the Prince of Wales for his gift of a signed portrait as a memento of his presidency.

III. The President sent to the Rt. Hon. the Earl of Balfour, K.G., O.M., F.R.S. (President, 1904), a telegram expressing good wishes, on behalf of the Association, on the occasion of Lord Balfour's eightieth birthday.

IV. The Council has had to deplore the loss by death of the following office-bearers and supporters: Dr. C. Chree, Lt.-Col. Allan Cunningham, Dr. H. F. Gadow, Dr. D. G. Hogarth, Dr. J. Horne, Prof. A. Liversidge, Mr. W. C. F. Newton, Sir A. E. Shipley, Sir A. Strahan.

The Council forwarded to the Linnean Society a message of condolence on the death of Dr. Daydon Jackson.

V. Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S., has been unanimously nominated to fill the office of President of the Association for the year 1929–30 (South African Meeting).

In accordance with the practice usual in connexion with an overseas meeting, the Council has appointed a committee, consisting of the President and General Officers, Lord Bledisloe, Sir William Bragg, Sir Richard Gregory and Sir Thomas Holland (with power to add to their number), to assist it in making arrangements for the South African Meeting. The Secretary of the Association has visited South Africa to confer with the authorities there on the arrangements, and has reported to the Council. The principal points in his report, which has been approved and adopted by the Council, are as follow:

He was in consultation with the local executive at Johannesburg, appointed by the South African Association for the Advancement of Science (the inviting body) to arrange the meeting; he also met the local Committee at Cape Town, and university, municipal, and other authorities at both these cities and at Pretoria. He

found everywhere enthusiasm for the visit; and the list of those members of the General Committee who indicated in April last the possibility that they would visit South Africa gave much satisfaction (and has since been published in the Press).

The Secretary found cogent reasons for amending the proposed date of the meeting, so that it may begin in Cape Town on July 22, 1929 (instead of July 29), and he took the responsibility of fixing this (as he was asked to do) on behalf of the Association. The Council is satisfied with his reasons for thus anticipating the decision of the General Committee, and desires to endorse them. They are:

(i) A general preference in South Africa for the earlier date, and, in particular, the greater convenience of the Universities of Cape Town and the Witwatersrand (Johannesburg), where most of the meetings will be held.

(ii) Opportunity for co-operation with the International Geological Congress at Pretoria, July 29–August 7.

(iii) Opportunity for co-operation with a Government Departmental Agricultural Conference, and a Pan-African Agricultural and Veterinary Congress, beginning on August 2 in Pretoria, the latter being transferred from Rhodesia to that city in view of the Association's visit.

Expected steamer sailings from England are more convenient with the earlier date.

The general outline of the Meeting is as follows:

Cape Town, July 22–July 28-29. Inaugural meeting, July 22, at which it is proposed that the president of the South African Association should address the meeting first, and that the new president of the British Association should then be installed, and reply. Sectional meetings, mornings only, July 23–26. Evening discourse, public lectures, excursions, &c.

Call at Kimberley, July 29–30.

Johannesburg, July 30-31–August 4. Presidential Address, July 31. Sectional Meetings, mornings only, July 31–August 3, and other arrangements as above. Pretoria, sectional transactions, &c., as appropriate in connexion with the co-operating congresses indicated above; continuing to August 7.

After the meetings, extended tours through the Union, to Victoria Falls, Rhodesia, Lourenço Marques, &c., as to which members will be afforded opportunity to indicate their preference.

It is proposed that in consideration of a grant by the South African Association to the British Association of a sum not exceeding £500 and reckoned at £1 per head of the number of persons involved, the British Association should admit to membership members of the South African Association in good standing down to June 1929, entitling them to attend the meeting and receive the report if desired. From 300 to 400 members are expected under this category, and the arrangement resembles that made in 1905.

The report entered into many details of arrangements, which the Council, through its committee mentioned above, has already taken in hand. Particulars are expected to be available at the Glasgow Meeting. It should be added that the Secretary, in making the journey, was the guest of the South African Association; and the Council, in gratefully accepting the invitation to him, offered to meet the costs incurred if a representative of the local executive should attend the Glasgow Meeting.

The gratifying intimation has since been received that Mr. James Gray, of Johannesburg, will do so in that capacity.

An offer has been received from the Rhodes Trustees, and has been gratefully accepted by the Council, to make a grant of £200 toward any further authoritative investigation at the ruins at Great Zimbabwe undertaken in connexion with the South African Meeting.

A generous invitation has been received from L'Association française pour l'Avancement des Sciences, and from the City of Le Havre, for members unable to take part in the South African Meeting, to attend that of the French association in Le Havre, as was done in 1914.

VI. Representatives of the Association have been appointed as follow:—

Institute of Chemistry, Jubilee Celebration	Prof. E. C. C. Baly.
Royal College of Physicians, Tercentenary of William Harvey	Sir Charles Sherrington.
Toronto University, Centenary Celebration	Sir Charles Sherrington.
International Etruscan Congress	Dr. Randall-MacIver.
University College, Nottingham, opening of new buildings	Prof. J. L. Myres.
National Association for the Prevention of Tuberculosis, Congress	Dr. J. G. Garson.
Meetings convened by the Management Research Groups to consider rationalisation in industry	The President and Secretary.

On the report concerning the meetings last mentioned, the Council resolved to welcome the proposal for management research groups as a step toward greater freedom in the interchange of information with a view to establishing mutual confidence and encouraging mutual service between enterprises of all kinds which depend for their efficiency on the methods and results of scientific investigations.

VII. The Council, in pursuance of instruction received from the General Committee, communicated to the British Science Guild the report of the joint committee, with a general approval of the conditions therein suggested upon which a union of the Guild with the Association might be effected.

Further action by the Council of the British Science Guild is awaited.

VIII. Resolutions referred by the General Committee at the Leeds Meeting to the Council for consideration, and if desirable, for action, were dealt with as follows:

(*a*) Information has been requested as to the proposed content of the republished reports of the Mathematical Tables Committee in collected form, with other tables, with a view to arriving at an estimate of cost. A first and provisional estimate has been made, indicating a cost of £350 for an edition of 1,000 of such a volume as is contemplated, or of £430 for an edition of 2,000. (Resolution of Section A.)

(*b*) The Director-General of the Ordnance Survey, on being consulted as to the publication of the survey of the St. Kilda islands, informed the Council of his willingness to undertake the publication, and subsequently that publication had taken place. (Resolution of Section E, supplemented by Sections C, D, H, K.)

(*c*) A resolution inviting the inclusion of geographical work in the programme of the proposed Great Barrier Reef Expedition was referred to the Great Barrier Reef Committee. The Council is informed that expert geographers are included in the staff of the expedition. (Resolution of Section E.)

(*d*) A letter[1] was received from the Scottish Board of Education in answer to representations made on the teaching of geography in Scotland (Resolution of Section E).

( ) In regard to the resolution authorising the Council to publish a new edition of 'Notes and Queries on Anthropology,' the Council has made an interim grant of £50 toward incidental expenses of the work of compilation, and awaits an estimate of the cost of publication. (Resolution of Section H.)

[1] For letter and discussion in Section E, see p. 639.

(*f*) A resolution dealing with the low percentage of productive forest area in Great Britain was adopted with the addition of a reference to the rapid depletion of forests in other parts of the Empire, and was communicated to the Empire Forestry Association and the Empire Marketing Board. (Resolution of Section K.)

(*g*) In regard to resolutions from the Conference of Delegates of Corresponding Societies, dealing with the preservation of British wild flora, the Council caused a circular letter to be addressed to 311 education authorities in England and Wales, inviting their support in strengthening and extending the movement toward this object, and received from some fifty of these authorities replies indicative of a realisation of the importance of the matter. The Council acknowledges with gratitude information placed at its disposal by the Home Office, and has remitted further consideration of the question to the committee nominated by Section K (Botany) to deal with it.

IX. The attention of the Council was drawn to the full account of the special sessions on textile subjects at the Leeds Meeting issued as a number of the Journal of the Textile Institute, Manchester, and to the warm appreciation of the action of the Council, therein expressed, in arranging these sessions.

X. The Council in its report for 1926–27 recorded its unsatisfactory negotiations with Government authorities on the subject of the introduction of cinematograph films into this country for scientific purposes and not for commercial use. The Council is glad to learn that the difficulty encountered has now been overcome by the action of H.M. Government in undertaking to accept the certificate of the Royal Society as to films stated to be illustrative of scientific investigations.

XI. The Council has received reports from the General Treasurer throughout the year. His accounts have been audited and are presented to the General Committee.

The Council made the following grants to research committees from the income of the Caird Fund:

Naples Table ..	£100	Seismology	£100

A sum of £10 10*s*. was voted toward the expenses of the Inquiry into the relationship of Technical Education to other forms of Education and to Industry and Commerce, upon which the Association was represented by Sir Robert Blair.

The Council has been informed that under the will of the late Lt.-Col. Allan Cunningham a legacy will accrue to the Association for the purpose of continuing the work of preparing new mathematical tables.

The Association, like the great majority of scientific societies, has been unable to recover income tax previously remitted upon income from invested funds. The cases regarded by the Inland Revenue authorities as test cases upon the liability of societies to taxation (Geologists' Association; Midland Counties Institution of Engineers) have been decided against the societies by the Special Commissioners and in the High Court of Justice. The Council is informed that appeals against these decisions have been lodged.

XII. The Corresponding Societies Committee has been nominated as follows: The President of the Association (*Chairman ex-officio*), Mr. T.

Sheppard (*Vice-Chairman*), the General Treasurer, the General Secretaries, Mr. C. O. Bartrum, Dr. F. A. Bather, Sir Richard Gregory, Sir David Prain, Sir John Russell, Mr. M. L. Sykes, Dr. C. Tierney.

The Council conveyed its congratulations to the Cardiff Naturalists' Society on the occasion of the Society's diamond jubilee.

XIII. The retiring Ordinary Members of the Council are Mr. E. N. Fallaize, Prof. J. P. Hill, Sir Thomas Holland, Prof. A. Smithells, Prof. T. B. Wood.

The Council nominates the following new members: Prof. C. Burt, Mr. C. G. T. Morison, Sir Josiah Stamp, leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of Ordinary Members is as follows:

Prof. J. H. Ashworth.
Rt. Hon. Lord Bledisloe.
Prof. A. L. Bowley.
Prof. C. Burt.
Prof. E. G. Coker.
Prof. W. Dalby.
Dr. H. H. Dale.
Sir J. S. Flett.
Sir Henry Fowler.
Sir R. A. Gregory.
C. T. Heycock.
A. R. Hinks.
Col. Sir H. G. Lyons.
C. G. T. Morison.
Dr. C. S. Myers.
Prof. T. P. Nunn.
Prof. A. O. Rankine.
C. Tate Regan.
Prof. A. C. Seward.
Dr. F. C. Shrubsall.
Dr. N. V. Sidgwick.
Dr. G. C. Simpson.
Sir Josiah Stamp.

XIV. The General Officers have been nominated by the Council as follows:—

General Treasurer: Sir Josiah Stamp.
General Secretaries: Prof. J. L. Myres, Dr. F. E. Smith.

During its present session the Council has again been deprived of the presence of Dr. E. H. Griffiths, General Treasurer, owing to ill-health, but it is gratefully recorded that he has not allowed this to deprive the Council of his valuable advice and reports on the finances of the Association, which have been presented on his behalf by Dr. F. E. Smith as acting treasurer. Nevertheless Dr. Griffiths has felt it necessary again to tender his resignation, and the Council, with the deepest regret, feels that he cannot again be pressed to withdraw it. In accordance with precedent, the Council has consulted a committee consisting of the President, General Officers and ex-Presidents, in considering the nomination to be made in the room of Dr. Griffiths.

XV. The following have been admitted as members of the General Committee: Dr. T. F. Chipp, Mr. Thurkill Cooke, Dr. Donald Patton, Mr. A. Lennox Stanton.

XVI. Consultation has taken place with authorities in York as to the possibility of holding the Centenary Meeting of the Association there in 1931. The Council, though appreciating the powerful sentiment which would attract the Association to its birthplace on this occasion, cannot but foresee difficulties associated mainly with the problem of housing a large number of visiting members at places distant from the city. The matter will be brought to the consideration of the General Committee at the Glasgow Meeting, and a possible alternative will be put forward.

DOWN HOUSE.

The following important announcement was made[1] to the General Committee of the Association, meeting in Glasgow on September 5, regarding Darwin's home, Down House, in the County of Kent. Mr. George Buckston Browne, Fellow of the Royal College of Surgeons of England and of the Society of Antiquaries, London, having acquired the property from Prof. Charles Galton Darwin, F.R.S., grandson of the naturalist, has transferred its possession to the British Association under the most liberal conditions and with an endowment amply sufficient for its maintainance and preservation for all time.

At present Down House serves as a private school. When the tenant's lease falls in or is acquired, the donor desires that the property be regarded as a gift to the nation and opened to visitors every day of the week between the hours of 10 and 6, without charge. He also desires that the Association should use Down House and grounds for the benefit of science. The donor has also suggested that certain of the rooms—particularly the old 'study,' in which the *Origin of Species* was written—should be furnished, as near as may be possible, as they were when Darwin lived in them. The donor has already taken steps to secure this end and has obtained the willing co-operation and greatest assistance from various members of the Darwin family. Indeed, without the generous co-operation of the Darwin family the transfer of ownership could not have been effected. The late Mrs. Litchfield, the third daughter of Charles Darwin, bequeathed for Down House her father's study chair and letter-weighing machine. Thanks also to the generosity of other members and friends of the Darwin family—Major Leonard Darwin, Prof. Charles G. Darwin, Mrs. Perrero, and Mrs. Berkeley Hill, together with acquisitions made by himself, Mr. Buckston Browne has already got together the nucleus of a Darwin collection for Down. He has commissioned the Hon. John Collier to paint replicas of his well-known portraits of Darwin and of Huxley to be hung at Down House; these commissions are already completed. It is hoped that the shelves of the old study may be filled with all editions of Darwin's works, and that Down House may become a repository of Darwiniana where students will have an opportunity of consulting all original documents concerning Darwin and his writings. Such an end can be attained only if the British Association succeeds in enlisting the sympathetic co-operation of all who may be the fortunate owners of articles which were in the possession of Darwin or were associated with his life.

The Donor.

Mr. George Buckston Browne was born in Manchester in 1850, the only son of a well-known medical man—Dr. Henry Browne, physician to the Manchester Royal Infirmary and Lecturer on Medicine to the Manchester Medical School. Dr. Henry Browne represented the fourth generation of a medical dynasty where son had succeeded father, the founder of the family having been Dr. Theophilus Browne of Derby who was townsman

[1] By Prof. Sir Arthur Keith, F.R.S.

and contemporary of Dr. Erasmus Darwin, grandfather of Charles Darwin. Mr. Buckston Browne continued the family tradition, representing the fifth medical generation. In 1866, at the age of sixteen, he matriculated as a student of London University, entered University College, was awarded medals in Anatomy, Chemistry and Midwifery, gained the gold medal for practical chemistry and the Liston gold medal in surgery. He became a member of the Royal College of Surgeons in 1874 and gained in open competition the house-surgeoncy to his hospital (University College Hospital) where he served under Sir John Erichsen. He also taught anatomy under Prof. Vines Ellis. No one ever trained himself more thoroughly for his profession.

After his term in hospital, Mr. Buckston Browne was invited by Sir Henry Thompson, one of the most distinguished and accomplished surgeons of the Victorian era, to become assistant and afterwards collaborator. In 1884 he began practice on his own account and became very closely, and very successfully, engaged in work. Indeed, his application to his profession was such that for twenty-seven years, in the earlier period of his career, he had neither a free day nor holiday. Mr. Buckston Browne has contributed important articles to the literature of his profession, but it was his practical ability, unerring insight, and skilled hand which gained him his success and the esteem of his colleagues and of his patients. In 1926 the Council of the Royal College of Surgeons conferred on him the diploma of Fellow in recognition of his services to surgery.

The donor of Down House has had, as his many friends well know, not only a successful life but also a very happy one.

Mr. Buckston Browne's only daughter is the wife of Mr. Hugh Lett, C.B.E., Surgeon to the London Hospital, and brother of a distinguished artiste, Miss Phyllis Lett. In the Lett family Mr. Buckston Browne possesses three charming grand-daughters.

But since the war death has laid a heavy hand upon his family. In 1919 he lost his only son, Lt.-Col. George Buckston Browne, who was awarded the Distinguished Service Order for action in the field. Lt.-Col. Buckston Browne left an only son. He also was struck down in 1924, dying from typhoid fever in South Africa. A long line was thus brought to a sudden end. In 1926 Mrs. Buckston Browne died, a devoted partnership of fifty-two years being thus ended. Mrs. Buckston Browne rests in the churchyard of her native village, Sparsholt, Hants. Here her husband has endowed an almshouse for aged villagers in her memory.

The History of Down[2] House.

It may not be amiss to recount some of the circumstances which led up to the appeal for the preservation of Darwin's home. Some years before his death the late Sir Arthur Shipley, Master of Christ's College, Cambridge, where Darwin was an undergraduate, wrote to a member of the British Association as follows: 'It seems to me that Down House

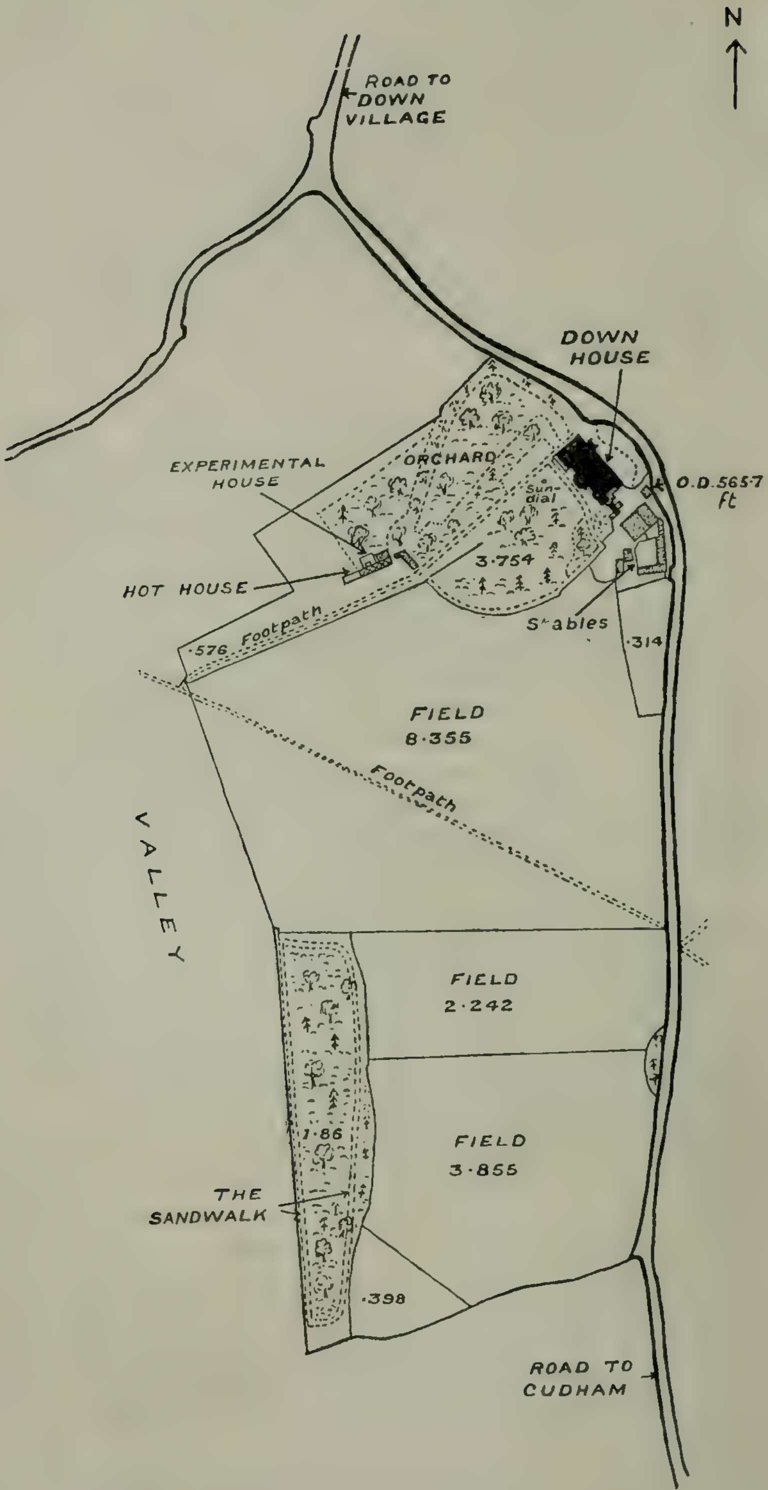
[2] On the Ordnance Survey maps the spelling is *Downe*, but as Darwin always wrote *Down* without an 'e' the latter spelling has been adopted.

ought to be a national possession. Do you know of any means by which this can be brought about ?' On the eve of the Leeds Meeting of the British Association on August 31, 1927, the Council of the Association considered this matter and empowered the then President (Sir Arthur Keith) to make a public appeal at the close of his presidential address to the assembled Association. An urgent S.O.S. was sent out with the happy result which all now know. It was with as much surprise as satisfaction that Sir Arthur Keith learned that the man who answered the call was a Fellow of his own College. Indeed, he knew Mr. Buckston Browne as a generous benefactor to that College and to the Harveian Society, but was unaware of his love for Darwin and for Down. It was later that he learned that Darwin's friend Huxley had long ago exerted an abiding influence on the donor of Down.

Darwin's Association with Down House.

Darwin was born at Shrewsbury, February 12, 1809. Down House was purchased for him by his father, Dr. Darwin, and he took up his residence there on September 14, 1842. Darwin was then in his thirty-fourth year; three years previously he had married his cousin, Emma Wedgewood. His two eldest children, William and Anne, were born in London; the third, Mary, was born and died just after arrival at Down. Then followed in 1843 Henrietta, who became Mrs. Litchfield; in 1845 George, who became Sir George Darwin, F.R.S., and whose son, Prof. Charles Darwin, F.R.S., succeeded to the ownership of Down and is the fifth of a succession of father and son who have been elected Fellows of the Royal Society—an unique record; in 1847 Elizabeth was born; in the following year Francis, who became Sir Francis Darwin, F.R.S.—a distinguished botanist and president of the British Association. His son, Bernard Darwin, is known to all as an exponent as well as an authority on golf. Leonard followed in 1850—Major Leonard Darwin, scientist, philanthropist and the founder and still active supporter of the Eugenics Society. Then came Horace, now Sir Horace Darwin, F.R.S., happily still alive. And last number 10, Charles Waring Darwin, who died in childhood. Down was thus the home of a large and happy family, perhaps the most gifted family ever born in England. There the great naturalist died on April 19, 1882, in his seventy-fourth year. He worked continuously at Down for almost forty years.

In that period he made his first draft of the *Origin of Species* (1842), he wrote his researches on the *Zoology of the Beagle*, on *Coral Reefs*, and prepared a new edition of a *Naturalist's Voyage*. Before he settled down to work at *Barnacles*, to which he gave seven years (1847–54), he prepared his papers on *Volcanic Islands* and on the *Geology of South America*. Preparations for the *Origin of Species*, which did not receive its final form until 1858–59, went on continuously from 1842 onwards. Then followed his inquiries into *Fertilisations of Orchids* (1862), *Variations of Animals and Plants under Domestication* (1868), *Descent of Man* (1871), the *Expression of the Emotions* (1872), *Movements and Habits of Climbing Plants* (1875); *Insectivorous Plants* appeared in the same year; *Cross and Self Fertilisation* in 1876, and his last work of all, one which was begun soon after he settled at Down, *The Formation of Vegetable Mould*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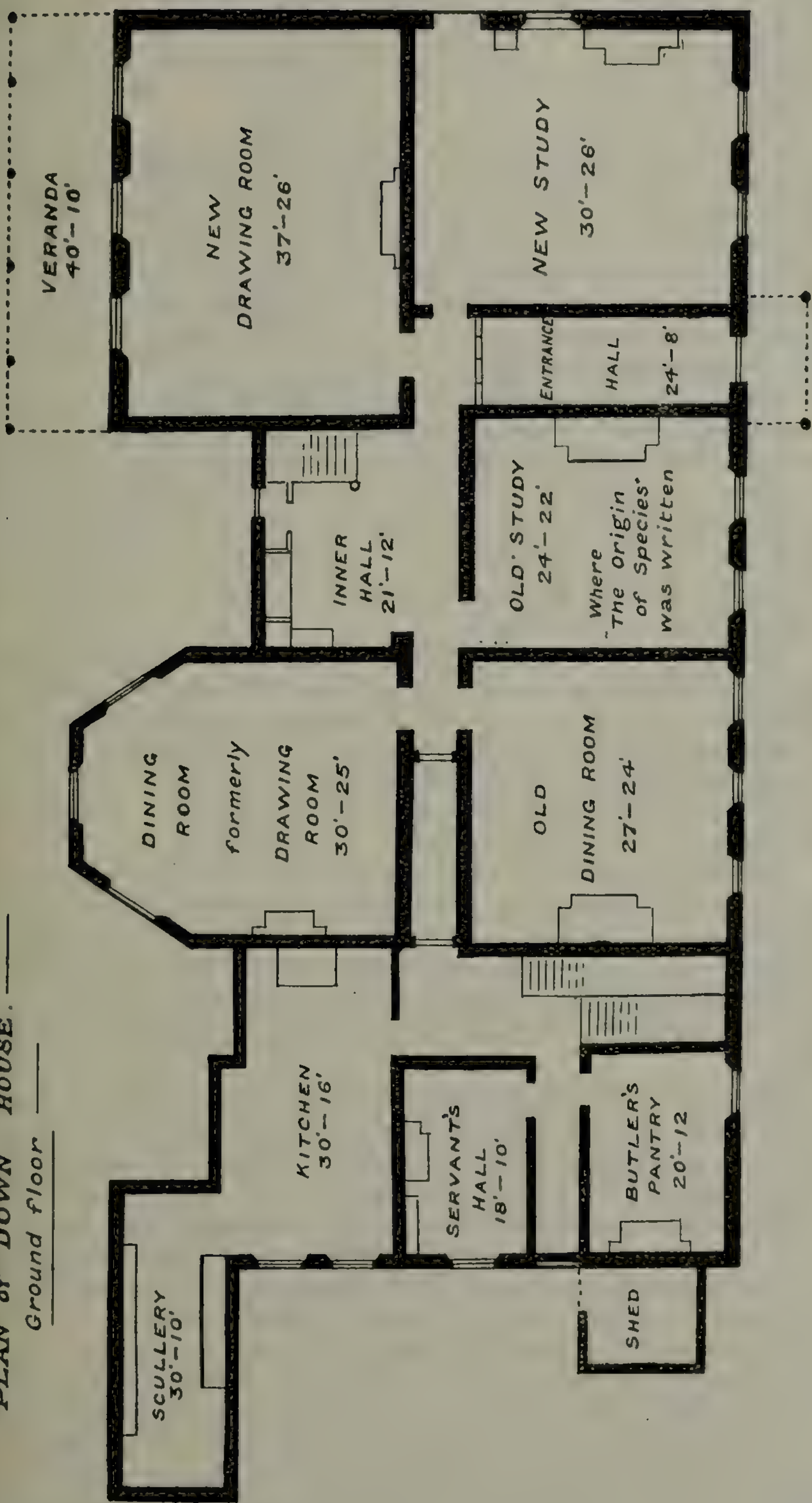

PLAN of DOWN HOUSE.
Ground floor

through the Action of Worms. No single home in the world can show such a record. Truly from Down Charles Darwin shook the world and gave human thought an impress which will endure for all time. Down is a priceless heirloom not only for England but for the civilised world. One of the greatest men of all time lived there.

As to the character of Down House, much is to be learned from the account which Sir Francis Darwin has given in his father's biography :—

'On September 14, 1842, my father left London with his family and settled at Down. In the autobiographical chapter his motives for moving into the country are briefly given. He speaks of the attendance at scientific societies and ordinary social duties as suiting his health so "badly that we resolved to live in the country, which we both preferred and have never repented of."

'The choice of Down was rather the result of despair than of actual preference ; my father and mother were weary of house-hunting, and the attractive points about the place thus seemed to them to counterbalance its somewhat more obvious faults. It had at least one desideratum—namely, quietness. Indeed, it would have been difficult to find a more retired place so near to London. . . . It is a place where newcomers are seldom seen, and the names occurring far back in the old church registers are still known in the village.

'The house stands a quarter of a mile from the village, and is built, like so many houses of the last century, as near as possible to the road—a narrow lane winding away to the Westerham high road. In 1842 it was dull and unattractive enough ; a square brick building of three storeys, covered with shabby whitewash and hanging tiles. The garden had none of the shrubberies or walls that now give shelter ; it was overlooked from the lane, and was open, bleak, and desolate.

'The house was made to look neater by being covered with stucco, but the chief improvement effected was the building of a large bow of three storeys. This bow became covered with a tangle of creepers, and pleasantly varied the south side of the house. The drawing-room, with its verandah opening into the garden, as well as the study in which my father worked during the later years of his life, were added at subsequent dates.

'Eighteen acres of land were sold with the house, of which twelve acres on the south side of the house form a pleasant field, scattered with fair-sized oaks and ashes. From this field a strip was cut off and converted into a kitchen garden, in which the experimental plot of ground was situated, and where the greenhouses were ultimately put up.'

To fill in some further details of this picture of Down we may also draw upon the description given by Mrs. Litchfield, in the life of her mother, Mrs. Darwin—(*Emma Darwin*, privately printed 1904).

'For some time there had been a growing wish on the part of my parents to live in the country. Their health made London undesirable in many ways, and they both preferred the freedom and quiet of a country life. They decided to buy a country house, but out of prudence resolved upon not going beyond a moderate price, and as they also wished to be near London, there was a weary search before they found anything at all suitable. In her little diary, under July 22, 1842, I find the entry "*went*

to '*Down*,' " and this I think must have been the first sight of her future home. It was bought for them by Dr. Darwin for about £2,200, and the purchase was quickly completed, for they moved in on September 14, 1842.

'Down was then ten miles from a station, and the whole neighbourhood was intensely rural and quiet, though only sixteen miles from London Bridge.'

The two accompanying plans, the data for which were obtained throug the kindness of Major Leonard Darwin, will give a precise idea of the extent of the property and of the plan of Darwin's home. Fig. 1 shows the arrangement and extent of the grounds; the figures indicate the acreage of each part. Down House is seen to be situated at 565·7 feet O.D. The plantation with the sand walk round it—Darwin's 'thinking path'—with the dry chalk valley beyond, are depicted; so, too, are the orchard, gardens and hot-houses. In Fig. 2 is given a plan of the ground floor of Down House, the dimensions of each room being indicated in feet. It will be seen to be a commodious house, and remains just as Darwin lived in it. He added a new wing—that which includes the 'New Study and the New Drawing Room.'

GENERAL MEETINGS, ETC., IN GLASGOW.

The Inaugural General Meeting was held on Wednesday, September 5, 1928, at 8.30 p.m., in the St. Andrew's Hall. After the Lord Provost of Glasgow and the Principal of the University of Glasgow had welcomed the Association, Prof. Sir William Bragg, F.R.S., assumed the Presidency of the Association, in succession to Prof. Sir Arthur Keith, F.R.S., and delivered an Address (for which see page 1) on 'Craftsmanship and Science.' A vote of thanks was proposed by Sir Henry Fowler, K.B.E.

On Thursday evening, September 6, a Reception and Dance were given by the Lord Provost and Corporation of the City of Glasgow, in the City Chambers. On Monday evening, September 10, a Reception was given by the Local Committee in the Kelvinside Art Gallery.

Evening Discourses.

Prof. E. A. Westermarck: 'The Study of Popular Sayings.' 8.30 p.m., September 7, Royal Technical College; being the Frazer Lecture on Social Anthropology (see p. 656).

Prof. F. G. Donnan, F.R.S.: 'The Mystery of Life.' 8.30 p.m., September 11, Royal Technical College (see p. 659).

Public Lectures.

The following were delivered under the joint auspices of the British Association and the Workers' Educational Association :—

Sir Josiah Stamp, G.B.E.: 'The Influence of Money on Civilisation.' 7 p.m., September 6, The University, Glasgow.

Mr. D. Ward Cutler: 'Food Chains in Nature.' 7.30 p.m., September 6, Public Library, Coatbridge.

Mr. W. H. O'N. Manning: 'The Psychological Study of the Worker's Environment.' 7.30 p.m., September 7, Museum Hall, Paisley.

Mr. A. Rex Knight: 'Psychology in the Workshop.' 7.30 p.m., September 7, St. Mungo's Hall, South York Street, Glasgow.

Prof. Henry Clay: 'Post-War Unemployment Problems.' 7.30 p.m., September 7, Town Hall, Motherwell.

Prof. H. H. Turner, F.R.S.: 'Our Sun.' 7.30 p.m., September 7, The University, Glasgow.

Prof. O. H. T. Rishbeth: 'The World's Surface re-made by Man.' 7.30 p.m., September 10, Co-operative Memorial Hall, King Street, Tradeston.

Concluding General Meeting.

The Concluding General Meeting was held in the Fore Hall of the University on Wednesday, September 12, at 12 noon, when the following resolutions were adopted with acclamation :—

The British Association most warmly thanks the Citizens and Corporation of the City of Glasgow, through the Right Honourable the Lord

Provost, for the City's generous hospitality on the occasion of the Meeting of the Association in 1928. The Association acknowledges the unremitting labour of Sir John Samuel and his able staff, to whose admirable organisation the success of the meeting is so largely due; and the especial gratitude of the Association is accorded to Sir John and his colleague Prof. Magnus Maclean for having again devoted their time to the work of local organisation as they did in 1901.

The British Association most gratefully acknowledges through the Principal the generous co-operation and hospitality of the University of Glasgow, on the occasion of the Meeting in 1928. The Association especially appreciates the comfort and smooth working of the Meeting which have resulted from having the magnificent buildings and resources of the University placed unreservedly at its disposal.

The British Association deeply appreciates the facilities afforded to its members to acquaint themselves with the manifold economic, industrial and other scientific interests of the city and vicinity of Glasgow, by the Royal Technical College, the Clyde Trust, and other public institutions, manufacturers and civic authorities, and thanks all these for their kindly hospitality.

RESOLUTIONS & RECOMMENDATIONS.

The following resolutions and recommendations were referred to the Council by the General Committee at Glasgow for consideration and, if desirable, for action :—

From Section E.

To recommend to Council that the British Association for the Advancement of Science call the attention of the Governments and Departments concerned to the urgent importance of securing as soon as possible the cohesion of surveys in the East African Dependencies, with a view to the early completion of the thirtieth meridian arc, which offers the best means of providing the essential unified framework upon which the whole of the surveys of East Africa—geodetic, topographical and geological—may be based without waste of effort.

From Section E.

To recommend to Council that the British Association represent to His Majesty's Government the desirability of completing as soon as possible the uniform map of Africa, published by the Geographical Section (General Staff), on the scale of 1 : 2,000,000, a map which forms the only satisfactory base for various distributional studies in Africa; and further, that on each sheet of the map to be issued in the future a diagram be inserted to indicate the relative reliability of different areas of the map.

From Section E.

To call the attention of His Majesty's Government to the need for supplementing the periodical revision of Ordnance Survey maps by emergency revisions of areas transformed by industrial or urban development, and to suggest that by making available, at the cost of reproduction, the data collected by the Ordnance Survey, both economy and efficiency would result in the planning and development of such areas.

From Section H.

That the Council be asked to take cognisance of the present high cost of foreign scientific publications with a view to ascertaining whether, or by what means, some reduction in cost may be secured.

From Section H.

That, in view of the urgent need for systematic study of the Australian aboriginal languages, the Commonwealth Government of Australia be approached with a view to ascertaining the possibility of pressing on with such study before it is too late.

From Section H.

That the Government of the Dominion of Canada be asked whether, in view of the interest of anthropologists in the available field work of the Anthropological Division of the Geological Survey of Canada, it would be possible to expedite the official publication of the results.

From Section H.

That the financial arrangements authorised after the Leeds Meeting in connection with the publication of a new edition of Notes and Queries on Anthropology be continued.

From Section H.

That the financial arrangements authorised after the Leeds Meeting in connection with anthropological research in South Africa be continued.

From Section J.

That H.M. Treasury be urged to relieve from key industries duty all apparatus intended for employment in research in laboratories in universities and other purely educational institutions.

From Section K.

That the importance of increased research in the methods of preservation of timber be urged, and that a determined effort be made to secure increased funds for this purpose.

From Section L.

That the Committee of Recommendations urge upon the General Committee and the Council the advisability of reprinting sufficient copies of the report on Science in School Certificate Examinations to enable the recorder to have available 200 copies for distribution to teachers, associations, educational journals and other authorities interested in the matter.

From Section L.

That the Committee of Recommendations urge on the General Committee and he Council of the Association the advisability of adding the words 'and past recorders' to Statute IX, 5, immediately following the words 'and past presidents.'

From the Conference of Delegates of Corresponding Societies.

That it appears desirable that the British Association for the Advancement of science should urge His Majesty's Government to stimulate the employment by local authorities of the powers already conferred upon them by Parliament for the preservation of scenic amenity in town and country.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

GENERAL TREASURER'S ACCOUNT

JULY 1, 1927, TO JUNE 30, 1928.

NOTE BY THE GENERAL TREASURER.

I take this opportunity of calling the attention of Members of the British Association to the loss we have sustained by the decisions of the Treasury and the judgment of the High Court in regard to the non-return of Income Tax. We are thus deprived of one-fifth of the income from our Investments.

I hope that, unless the judgment referred to should be reversed, Members of the Association and all workers in Science throughout the country will join in an effort to obtain special legislation on this matter.

Our Investments are of two kinds: those made out of the funds of the Association and those given us by generous benefactors. It was hoped by this means to obtain an annual sum which would be of real value for the promotion of research, and at no time was it contemplated to devote so considerable a portion of the resulting income as a tribute to the national Treasury.

As regards the past session's Accounts it will be seen that we are carrying over a credit balance of £476 5*s*. 1*d*., and this may appear satisfactory.

It should be remembered, however, that had it not been for Sir Alfred Yarrow's generous and timely gift this credit balance would have been converted into a deficit.

By the conditions of that gift, however, we are each year diminishing our capital, and it is to be hoped that future benefactors will bear this in mind.

In conclusion I beg to thank the General Committee, the Council and the Members of the Association for the consideration they have shown me during my tenure of office and to express my regret that physical disability has made my resignation inevitable.

E. H. GRIFFITHS.

July 23, 1928.

Balance Sheet,

Corresponding Figures June 30, 1927. £ s. d.	LIABILITIES.		£ s. d.	£ s. d.
	To Capital Accounts—			
	General Fund—			
	As at July 1, 1927		10,640 15 2	
	Caird Gift—Radio-Activity Investigation—			
	As at July 1, 1927		52 3 11	
10,640 15 2				10,692 19 1
	As per contra (Subject to Depreciation in Value of Investments)			
	„ *Caird Fund*—			
9,582 16 3	As per contra . . . . (Subject to Depreciation in Value of Investments)			9,582 16 3
	„ *Caird Fund Revenue Account*—			
	Balance as at July 1, 1927		634 16 6	
	Add Excess of Income over Expenditure for year		80 5 0	
634 16 6	As per contra			715 1 6
52 3 11	„ *Caird Gift—Radio-Activity Investigation* . .			—
	„ *Sir T. Bramwell's Gift* for Enquiry into Prime Movers, 1931—			
	£50 Consols now accumulated to £145 1*s.* 3*d.*,			
69 3 3	as per contra			72 13 8
10,000 0 0	„ *Sir Charles Parsons' Gift*—as per contra . .			10,000 0 0
	„ *Sir Alfred Yarrow's Gift*—			
	Balance at July 1, 1927		10,000 0 0	
	Less Transferred to Income and Expenditure Account under the terms of the Gift		300 0 0	
10,000 0 0	As per contra			9,700 0 0
	„ *Life Compositions*—			
	As at July 1, 1927		1,128 12 2	
	Add Received during year . . .		180 0 0	
1,128 12 2	As per contra			1,308 12 2
	„ *Toronto University Presentation Fund*—			
	As at July 1, 1927		182 1 4	
	Add Refund in respect of third Medal, 1927		0 17 6	
	Dividends		8 15 0	
			191 13 10	
	Less Awards given		8 15 0	
182 1 4	As per contra			182 18 10
	„ *Prof. A. W. Scott's Legacy*—			
Nil	As per contra			250 0 0
	„ *Royal Charter Expenses*—			
	Donation—A. A. Campbell-Swinton . .		200 0 0	
	Less Expenses incurred to date . .		152 0 9	
Nil	As per contra			47 19 3
	„ Sundry Creditors		145 15 7	
	„ Income and Expenditure Account—			
	Balance at July 1, 1927 . .	£6,027 1 4		
	Less Proportion of purchase of War Loan (Sir A. Yarrow's Gift) last year representing accrued interest . .	169 7 0		
		5,857 14 4		
	Add Excess of Income over Expenditure for the year .	476 5 1		
			6,333 19 5	
6,027 1 4				6,479 15 0
48,317 9 11				£49,032 15 9

I have examined the foregoing Accounts with the Books and Vouchers and certify the same Approved,

ARTHUR L. BOWLEY, A. W. KIRKALDY, } *Auditors.*

July 13, 1928.

June 30, 1928.

Corresponding Figures June 30, 1927. £ s. d.	ASSETS.	£ s. d.	£ s. d.
	By Investments on Capital Accounts—		
	General Fund—		
	£4,651 10*s.* 5*d.* Consolidated 2½ per cent. Stock at cost	3,942 3 3	
	£3,600 India 3 per cent. Stock at cost .	3,522 2 6	
	£879 14*s.* 9*d.* £43 Great Indian Peninsula Railway 'B' Annuity at cost . . .	827 15 0	
	£52 12*s.* 7*d.* War Stock (Post Office Issue) at cost	54 5 2	
	£834 16*s.* 6*d.* 4½ per cent. Conversion Loan at cost	835 12 4	
	£1,400 War Stock 5 per cent. 1929/47 at cost	1,393 16 11	
	£84 National Savings Certificates, now £94 7*s.* 4½ per cent. Conversion Stock, 1940/44 .	62 15 0	
	Cash at Bank	54 8 11	
10,640 15 2			10,692 19 1
	£7,931 19s. 11d. Value of Stocks at date, £8,188 11*s.* 4*d.*		
	,, *Caird Fund*—		
	£2,627 0*s.* 10*d.* India 3½ per cent. Stock at cost	2,400 13 3	
	£2,100 London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock at cost	2,190 4 3	
	£2,500 Canada 3½ per cent. 1930/50 Registered Stock at cost	2,397 1 6	
	£2,000 Southern Railway Consolidated 5 per cent. Preference Stock at cost . . .	2,594 17 3	
9,582 16 3			9,582 16 3
	£7,116 15s. 10d. Value at date, £7,342 6*s.* 8*d.*		
	,, *Caird Fund Revenue Account*—		
634 16 6	Cash at Bank		715 1 6
	,, *Caird Gift*—		
52 3 11	*Cash at Bank*		—
	,, *Sir T. Bramwell's Gift*—		
	£138 14 11 Self-Accumulating Consolidated Stock as per last Balance Sheet	69 3 3	
	6 6 4 *Add* Accumulations to June 30, 1928 . . .	3 10 5	
69 3 3			72 13 8
	£145 1 3		
	£75 5s. 4d. Value at date, £81 4*s.* 8*d.*		
	,, *Sir Charles Parsons' Gift*—		
10,000 0 0	£10,300 4½ per cent. Conversion Loan .		10,000 0 0
	£9,888. Value at date, £10,145 10*s.*		
	,, *Sir Alfred Yarrow's Gift*—		
	£10,000 5 per cent. War Loan, as per last Account	10,169 7 0	
	Less Accrued Dividends now transferred to Income and Expenditure Account . .	169 7 0	
		10,000 0 0	
	Less Sale of Stock under the terms of the Gift	300 0 0	
10,169 7 0	Value at date, £9,857 12*s.* 6*d.*		9,700 0 0
	,, *Life Compositions*—		
	£1,921 12*s.* 10*d.* Local Loans at cost .	1,245 0 0	
	Value at date, £1,249 1*s.* 5*d.*		
	Cash at Bank	63 12 2	
1,128 12 2			1,308 12 2
	,, Toronto University Presentation Fund—		
	£175 5 per cent. War Stock at cost . .	178 11 4	
	£176 10s. 7d. Value at date, £177 16*s.* 11*d.*		
	Cash at Bank	4 7 6	
182 1 4			182 18 10
	,, *Prof. A. W. Scott's Legacy*—		
Nil	£326 9*s.* 10*d.* 3½ per cent. Conversion Stock at cost		250 0 0
	Value at date, £255 1*s.* 8*d.*		
	,, *Royal Charter Expenses*—		
—	Cash at Bank		47 19 3
	,, Revenue Account—		
	£2,098 1*s.* 9*d.* Consolidated 2½ per cent. Stock at cost	1,200 0 0	
	£4,338 6*s.* 2*d.* Conversion 3½ per cent. Stock at cost	3,300 0 0	
	£400 5 per cent. War Loan Inscribed Stock at cost	404 16 0	
	Value at date, £4,970 14*s.* 8*d.*		
	Sundry Debtors	380 9 7	
	Cash at Bank	1,139 1 2	
	Cash in Hand	55 8 3	
5,857 14 4			6,479 15 0
48,317 9 11			£49,032 15 9

to be correct. I have also verified the Balances at the Bankers and the Investments.

W. B. KEEN,
Chartered Accountant.

Income and

FOR THE YEAR ENDED

EXPENDITURE.

Corresponding Period June 30, 1927. £ s. d.		£ s. d.	£ s. d.
20 16 8½	To Heat, Lighting and Power	24 2 1	
65 18 5	,, Stationery	58 16 3	
1 0 0	,, Rent	1 0 0	
180 2 11	,, Postages	191 12 0	
149 0 11	,, Travelling Expenses	165 19 1	
30 10 6	,, Exhibitioners	91 13 8	
205 2 9½	,, General Expenses	212 3 11	
652 12 3		745 7 0	
1,254 17 0	,, Salaries and Wages	1,335 9 0	
75 0 0	,, Pension Contribution	75 0 0	
1,566 8 5	,, Printing, Binding, etc.	1,385 16 11	
			3,541 12 11
3,548 17 8			
—	,, The Secretary's Travelling Expenses to South Africa, recoverable as per contra		145 2 2
—	,, Dr. Klercker's Research Committee, Donation per contra		22 0 0
	,, Grants to Research Committees—		
	Quaternary Peats Committee	90 0 0	
	Macedonia Committee	50 0 0	
	Plymouth Committee	35 0 0	
	Derbyshire Caves Committee	50 0 0	
	Bronze Implements Committee	100 0 0	
	Egyptian Peasants Committee	100 0 0	
	Vasoligation Committee	10 0 0	
	Zoological Record Committee	50 0 0	
	Pigment in Insecta Committee	15 0 0	
	Medullary Centres Committee	17 0 0	
	Vocational Tests Committee	14 0 0	
	Kiltorcan Committee	10 0 0	
	Oxfordshire Villages Committee	15 0 0	
	Transplant Committee	25 0 0	
	Rose Hybrids Committee	10 0 0	
	Ductless Glands Committee	30 0 0	
	Critical Sections Committee	30 0 0	
	Taxation Committee	20 0 0	
	Sex Physiology Committee	10 0 0	
	Upland Bog-waters Committee	22 1 0	
	Phytogeography of the Balkan Peninsula Committee	50 0 0	
	Great Barrier Reef Committee	200 0 0	
	Ultra-Violet Light Committee	60 0 0	
	Zoological Bibliography Committee	1 0 0	
	Absorption Spectra Committee	10 0 0	
	Population Map of Great Britain Committee	25 0 0	
561 10 0			1,049 1 0
1,032 2 10	,, Balance, being Excess of Income over Expenditure for the year		476 5 1
5,142 10 6			£5,234 1 2

Caird

EXPENDITURE.

£ s. d.		£ s. d.	£ s. d.
	To Grants Paid—		
100 0 0	Seismology Committee	100 0 0	
100 0 0	Naples Tables Committee	100 0 0	
Nil	Technical Education Committee	10 10 0	
			210 10 0
164 11 8	,, Balance, being Excess of Income over Expenditure for the year		80 5 0
364 11 8			£290 15 0

Expenditure Account

JUNE 30, 1928.

INCOME.

Corresponding Period June 30, 1927. £	s.	d.		£	s.	d.	£	s.	d.
168	10	0	By Annual Members (Including £60, 1928/29) .				185	10	0
1,669	15	0	,, Annual Temporary Members (Including £362 10*s.*, 1928/29)				1,508	5	0
168	0	0	,, Annual Members with Report (Including £207, 1928/29)				523	10	0
153	15	0	,, Transferable Tickets (Including £7 10*s.*, 1928/29)				108	15	0
91	0	0	,, Students' Tickets (Including £14, 1928/29) . (Total Tickets as above, issued in advance for 1928/9 Glasgow Meeting, £651)				131	0	0
—			,, The Secretary's Travelling Expenses to South Africa, recoverable from the South African Association, per contra				145	2	2
—			,, Donation—Dr. Klercker, per contra . .				22	0	0
—			,, Lift Rent				5	0	0
70	3	8	,, Interest on Deposits				47	7	6
621	5	6	,, Sale of Publications				705	17	6
463	6	11	,, Advertisement Revenue				223	15	3
181	13	0	,, *Income Tax recovered*				—		
27	12	11	,, Unexpended Balance of Grants returned .				8	13	5
3	3	4	,, Liverpool Exhibitioners				22	10	0
			,, Dividends—						
£135	0	0	Consols	135	0	0			
86	8	0	India 3 per cent. Stock	86	8	0			
26	11	6	Great Indian Peninsula Rly. 'B' Annuity	26	13	3			
30	1	2	4½ per cent. Conversion Loan . .	30	1	2			
370	16	0	Ditto, Sir Charles Parsons' Gift . .	370	16	0			
73	8	9	3½ per cent. Conversion Loan . .	130	12	4			
43	7	3	Local Loans	53	11	10			
58	12	6	War Stock	68	12	6			
400	0	0	Ditto, Series 'A,' Sir A. Yarrow's Gift	388	0	0			
1,224	5	2					1,289	15	1
			By Sir Alfred Yarrow's Gift—						
			Proceeds of Sale of £300 War Loan, in accordance with terms of the Gift	300	0	0			
			Profit on Sale	7	0	3			
—							307	0	3
5,142	10	6					£5,234	1	2

Fund.

INCOME.

£	s.	d.		£	s.	d.	£	s.	d.
			By Dividends—						
£73	11	0	India 3½ per cent. Stock	73	11	0			
70	0	0	Canada 3½ per cent. Stock	70	0	0			
67	4	0	London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock .	67	4	0			
80	0	0	Southern Railway Consolidated 5 per cent. Preference Stock	80	0	0			
290	15	0					290	15	0
73	16	8	*By Income Tax recovered*				—		
364	11	8					£290	15	0

RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN GLASGOW, 1928.

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

Seismological Investigations.—Prof. H. H. Turner (*Chairman*), Mr. J. J. Shaw (*Secretary*), Mr. C. Vernon Boys, Dr. J. E. Crombie, Dr. C. Davison, Sir F. W. Dyson, Sir R. T. Glazebrook, Dr. H. Jeffreys, Prof. H. Lamb, Sir J. Larmor, Prof. A. E. H. Love, Prof. H. M. Macdonald, Dr. A. Crichton Mitchell, Mr. R. D. Oldham, Prof. H. C. Plummer, Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, Sir A. Schuster, Sir Napier Shaw, Sir G. T. Walker, Dr. F. J. W. Whipple. **£100** (Caird Fund grant).

Tides.—Prof. H. Lamb (*Chairman*), Dr. A. T. Doodson (*Secretary*), Dr. G. R. Goldsbrough, Dr. H. Jeffreys, Prof. J. Proudman, Prof. G. I. Taylor, Prof. D'Arcy W. Thompson, Commander H. D. Warburg.

Annual Tables of Constants and Numerical Data, chemical, physical, and technological. —Sir E. Rutherford (*Chairman*), Prof. A. W. Porter (*Secretary*), Mr. Alfred Egerton. **£5.**

Calculation of Mathematical Tables.—Prof. J. W. Nicholson (*Chairman*), Dr. J. R. Airey (*Secretary*), Mr. T. W. Chaundy, Dr. L. J. Comrie, Dr. A. T. Doodson, Prof. L. N. G. Filon, Dr. R. A. Fisher, Dr. J. Henderson, Prof. E. W. Hobson, Mr. J. O. Irwin, Profs. Alfred Lodge, A. E. H. Love, and H. M. Macdonald, Dr. J. F. Tocher, Dr. J. Wishart.

Investigation of the Upper Atmosphere.—Sir Napier Shaw (*Chairman*), Mr. C. J. P. Cave (*Secretary*), Prof. S. Chapman, Mr. J. S. Dines, Mr. L. H. G. Dines, Dr. G. M. Dobson, Capt. F. Entwistle, Commr. L. G. Garbett, Sir R. T. Glazebrook, Col. E. Gold, Dr. H. Jeffreys, Dr. H. Knox-Shaw, Sir J. Larmor, Mr. R. G. K. Lempfert, Prof. F. A. Lindemann, Dr. W. Makower, Mr. J. Patterson, Sir J. E. Petavel, Dr. L. F. Richardson, Sir A. Schuster, Dr. G. C. Simpson, Prof. H. H. Turner, Sir G. T. Walker, Dr. F. J. W. Whipple.

SECTION B.—CHEMISTRY.

To consider the possibilities of publishing a compilation of recent material on the subject of Colloid Chemistry.—Prof. F. G. Donnan (*Chairman*), Dr. W. Clayton (*Secretary*), Mr. E. Hatschek, Prof. W. C. McC. Lewis, Dr. E. K. Rideal, Sir R. Robertson.

Absorption Spectra and Chemical Constitution of Organic Compounds.—Prof. I. M. Heilbron (*Chairman*), Prof. E. C. C. Baly (*Secretary*), Prof. A. W. Stewart.

SECTION C.—GEOLOGY.

To excavate Critical Sections in the Palæozoic Rocks of England and Wales.—Prof. W. W. Watts (*Chairman*), Prof. W. G. Fearnsides (*Secretary*), Mr. W. S. Bisat, Dr. H. Bolton, Prof. W. S. Boulton, Mr. E. S. Cobbold, Prof. A. H. Cox, Mr. E. E. L. Dixon, Dr. Gertrude Elles, Prof. E. J. Garwood, Prof. H. L. Hawkins, Prof. V. C. Illing, Prof. O. T. Jones, Prof. J. E. Marr, Dr. F. J. North, Mr. J. Pringle, Dr. T. F. Sibly, Dr. W. K. Spencer, Dr. A. E. Trueman, Dr. F. S. Wallis. **£25.**

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.—Prof. E. J. Garwood (*Chairman*), Prof. S. H. Reynolds (*Secretary*), Mr. C. V. Crook, Mr. A. S. Reid, Prof. W. W. Watts, Mr. R. Welch.

To investigate the Quaternary Peats of the British Isles.—Prof. P. F. Kendall (*Chairman*), Mr. L. H. Tonks (*Secretary*), Prof. P. G. H. Boswell, Miss Chandler, Prof. H. J. Fleure, Dr. E. Greenly, Prof. J. W. Gregory, Prof. G. Hickling, Mr. J. de W. Hinch, Mr. R. Lloyd Praeger, Mrs. Reid, Dr. K. S. Sandford, Mr. T. Sheppard, Mr. J. W. Stather, Mr. A. W. Stelfox, Mr. C. B. Travis, Dr. A. E. Trueman, Mr. W. B. Wright. **£10.**

To investigate Critical Sections in the Tertiary Rocks of the London Area. To tabulate and preserve records of new excavations in that area.—Prof. W. T. Gordon (*Chairman*), Dr. S. W. Wooldridge (*Secretary*), Miss M. C. Crosfield, Prof. H. L. Hawkins, Prof. G. Hickling. **£10.**

To consider the opening up of Critical Sections in the Mesozoic Rocks of Yorkshire.—Prof. P. F. Kendall (*Chairman*), Mr. M. Odling (*Secretary*), Prof. H. L. Hawkins, Mr. F. Petch, Dr. Spath, Mr. J. W. Stather, Mr. H. C. Versey.

To assemble information regarding the Distribution of Cleavage in North and Central Wales.—Prof. W. G. Fearnsides (*Chairman*), Prof. P. G. H. Boswell and Mr. W. H. Wilcockson (*Secretaries*), Prof. A. H. Cox, Mr. I. S. Double, Dr. Gertrude Elles, Prof. O. T. Jones, Dr. E. Greenly, Mr. W. B. R. King, Prof. W. J. Pugh, Dr. Bernard Smith, Dr. A. K. Wells, Dr. L. J. Wills.

SECTIONS C, D, E, K.—GEOLOGY, ZOOLOGY, GEOGRAPHY, BOTANY.

To organise an expedition to investigate the Biology, Geology, and Geography of the Australian Great Barrier Reef.—Rt. Hon. Sir M. Nathan (*Chairman*), Prof. J. Stanley Gardiner and Mr. F. A. Potts (*Secretaries*), Hon. John Huxham (*Treasurer*), Sir Edgeworth David, Prof. W. T. Gordon, Prof. A. C. Seward, and Dr. Herbert H. Thomas (*from Section C*); Mr. E. Heron Allen, Dr. E. J. Allen, Prof. J. H. Ashworth, Dr. G. P. Bidder, Dr. W. T. Calman, Sir Sidney Harmer, Dr. C. M. Yonge (*from Section D*); Dr. R. N. Rudmose Brown, Sir G. Lenox Conyngham, Mr. F. Debenham, Admiral Douglas, Mr. A. R. Hinks (*from Section E*); Prof. F. E. Fritsch, Dr. Margery Knight, Prof. A. C. Seward (*from Section K*). **£200.**

SECTION D.—ZOOLOGY.

To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.—Prof. E. S. Goodrich (*Chairman*), Prof. J. H. Ashworth (*Secretary*), Dr. G. P. Bidder, Prof. F. O. Bower, Prof. Munro Fox, Sir W. B. Hardy, Sir Sidney Harmer, Prof. E. W. MacBride. **£100** (Caird Fund grant).

Zoological Bibliography and Publication.—Prof. E. B. Poulton (*Chairman*), Dr. F. A. Bather (*Secretary*), Mr. E. Heron-Allen, Dr. W. T. Calman, Dr. P. Chalmers Mitchell, Mr. W. L. Sclater.

To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. J. H. Ashworth (*Chairman and Secretary*), Prof. W. J. Dakin, Prof. J. Stanley Gardiner, Prof. S. J. Hickson. **£50.**

To co-operate with other Sections interested, and with the Zoological Society, for the purpose of obtaining support for the Zoological Record.—Sir Sidney Harmer (*Chairman*), Dr. W. T. Calman (*Secretary*), Prof. E. S. Goodrich, Prof. D. M. S. Watson. **£50.**

On the Influence of the Sex Physiology of the Parents on the Sex-Ratio of the Offspring.—Prof. W. J. Dakin (*Chairman*), Mrs. Bisbee (*Secretary*), Prof. Carr-Saunders, Miss E. C. Herdman. **£10.**

Investigations on Pigment in the Insecta.—Prof. W. Garstang (*Chairman*), Dr. J. W. Heslop Harrison (*Secretary*), Prof. A. D. Peacock, Prof. E. B. Poulton. **£6.**

To consider the position of Animal Biology in the School Curriculum and matters relating thereto.—Prof. R. D. Laurie (*Chairman and Secretary*), Mr. H. W. Ballance, Dr. Kathleen E. Carpenter, Prof. W. J. Dakin, Mr. O. H. Latter, Prof. E. W. MacBride, Miss M. McNicol, Miss A. J. Prothero.

A Preliminary Survey of Certain Tropical Lakes in Kenya in 1929.—Prof. J. Stanley Gardiner (*Chairman*), Miss P. M. Jenkin (*Secretary*), Dr. W. T. Calman, Prof. J. Graham Kerr, Mr. J. T. Saunders. **£50.**

SECTIONS D, I, K.—ZOOLOGY, PHYSIOLOGY, BOTANY.

Nomenclature of Cell Structures.—Prof. C. Lovatt Evans (*Chairman*), (*Secretary*), Prof. H. E. Roaf (for Section I), Dr. K. B. Blackburn, Dr. Margery Knight (for Section K).

SECTIONS D, K.—ZOOLOGY, BOTANY.

To consider the means to be adopted for the establishment of a suitably equipped fresh-water biological station.—Prof. F. E. Fritsch (*Chairman*), Prof. F. Balfour Browne (*Secretary*), Dr. B. M. Griffiths, Dr. Gurney, Prof. H. S. Holden, Dr. W. H. Pearsall, Dr. E. S. Russell, Mr. J. T. Saunders.

SECTION E.—GEOGRAPHY.

To report further as to the method of construction and reproduction of a Population Map of the British Isles with a view to the census of 1931.—Mr. H. O. Beckit (*Chairman*), Mr. J. Cossar (*Secretary*), Mr. J. Bartholomew, Mr. F. Debenham, Prof. C. B. Fawcett, Prof. H. J. Fleure, Mr. R. H. Kinvig, Mr. A. G. Ogilvie, Prof. O. H. T. Rishbeth, Prof. P. M. Roxby, Mr. A. Stevens, Col. H. S. L. Winterbotham. **£50.**

To inquire into the present state of Knowledge of the Human Geography of Tropical Africa, and to make recommendations for furtherance and development.—Mr. J. McFarlane (*Chairman*), Mr. A. G. Ogilvie (*Secretary*), Mr. W. H. Barker, Mr. Francis R. Rodd, Prof. P. M. Roxby, Col. H. S. L. Winterbotham. **£25.**

SECTIONS E, L.—GEOGRAPHY, EDUCATION.

To report on the present position of Geographical Teaching in Schools and of Geography in the training of teachers ; to formulate suggestions for a syllabus for the teaching of geography both to Matriculation Standard and in Advanced Courses and to report, as occasion arises, to Council through the Organising Committee of Section E upon the practical working of Regulations issued by the Board of Education (including Scotland) affecting the position of Geography in Schools and Training Colleges.—Prof. T. P. Nunn (*Chairman*), Mr. W. H. Barker (*Secretary*), Mr. A. B. Archer, Mr. L. Brooks, Mr. C. C. Carter, Mr. J. Cossar, Prof. H. J. Fleure, Mr. O. J. R. Howarth, Mr. H. E. M. Icely, Mr. J. McFarlane, Rt. Hon. Sir Halford J. Mackinder, Prof. J. L. Myres, Dr. Marion Newbigin, Mr. A. G. Ogilvie, Mr. A. Stevens (*from Section E*) ; Mr. C. E. Browne, Sir R. Gregory, Mr. E. R. Thomas, Miss O. Wright (*from Section L*). **£5.**

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

To investigate certain aspects of Taxation in relation to the Distribution of Wealth.—Sir Josiah Stamp (*Chairman*), Mr. R. B. Forrester (*Secretary*), Prof. E. Cannan, Prof. H. Clay, Mr. W. H. Coates, Miss L. Grier, Prof. H. M. Hallsworth, Prof. D. H. Macgregor, Prof. J. G. Smith, Mr. J. Wedgwood, Sir A. Yarrow, Prof. Allyn Young. **£25.**

SECTION G.—ENGINEERING.

Earth Pressures.—Mr. F. E. Wentworth-Sheilds (*Chairman*), Dr. J. S. Owens (*Secretary*), Prof. A. Barr, Prof. G. Cook, Mr. T. E. N. Fargher, Prof. A. R. Fulton, Prof. F. C. Lea, Mr. R. V. Southwell, Dr. R. E. Stradling, Dr. W. N. Thomas, Mr. E. G. Walker, Mr. J. S. Wilson. Unexpended balance.

Electrical Terms and Definitions.—Prof. Sir J. B. Henderson (*Chairman*), Prof. F. G. Baily and Prof. G. W. O. Howe (*Secretaries*), Prof. W. Cramp, Dr. W. H. Eccles, Prof. C. L. Fortescue, Prof. E. W. Marchant, Dr. F. E. Smith, Prof. L. R. Wilberforce, with Dr. A. Russell and Mr. C. C. Wharton.

Stresses in overstrained materials.—Sir Henry Fowler (*Chairman*), Mr. J. G. Docherty (*Secretary*), Prof. B. P. Haigh, Mr. J. S. Wilson. **£5.**

SECTION H.—ANTHROPOLOGY.

To report on the Distribution of Bronze Age Implements.—Prof. J. L. Myres (*Chairman*), Mr. H. J. E. Peake (*Secretary*), Mr. A. Leslie Armstrong, Mr. H. Balfour, Prof. T. H. Bryce, Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Dr. Cyril Fox, Mr. G. A. Garfitt. **£50** and unexpended balance.

To conduct Explorations with the object of ascertaining the Age of Stone Circles.—Sir C. H. Read (*Chairman*), Mr. H. Balfour (*Secretary*), Dr. G. A. Auden, Mr. O. G. S. Crawford, Sir W. Boyd Dawkins, Dr. J. G. Garson, Sir Arthur Evans, Prof. J. L. Myres, Mr. H. J. E. Peake.

To excavate Early Sites in Macedonia.—Prof. J. L. Myres (*Chairman*), Mr. S. Casson (*Secretary*), Dr. W. L. H. Duckworth, Mr. M. Thompson. **£50.**

To report on the Classification and Distribution of Rude Stone Monuments.—Mr. G. A. Garfitt (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mr. O. G. S. Crawford, Miss R. M. Fleming, Prof. H. J. Fleure, Dr. C. Fox, Mr. G. Marshall, Prof. J. L. Myres, Mr. H. J. E. Peake, Rev. Canon Quine.

The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.—Mr. E. Torday (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Dr. G. A. Auden, Dr. H. A. Auden, Mr. L. J. P. Gaskin, Mr. E. Heawood, Prof. J. L. Myres.

To report on the probable sources of the supply of Copper used by the Sumerians.—Mr. H. J. E. Peake (*Chairman*), Mr. G. A. Garfitt (*Secretary*), Mr. H. Balfour, Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Prof. C. H. Desch, Prof. H. J. Fleure, Prof. S. Langdon, Mr. E. Mackay, Sir Flinders Petrie, Mr. C. Leonard Woolley. **£100.**

To conduct Archæological and Ethnological Researches in Crete.— (*Chairman*), Prof. J. L. Myres (*Secretary*), Dr. W. L. H. Duckworth, Sir A. Evans, Dr. F. C. Shrubsall.

The Investigation of a hill fort site at Llanmelin, near Caerwent.—Dr. Willoughby Gardner (*Chairman*), Dr. Cyril Fox (*Secretary*), Dr. T. Ashby, Prof. H. J. Fleure, Mr. H. J. E. Peake, Prof. H. J. Rose, Dr. R. Mortimer Wheeler.

To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern.—Sir A. Keith (*Chairman*), Prof. J. L. Myres (*Secretary*), Mr. M. C. Burkitt, Dr. R. V. Favell, Mr. G. A. Garfitt, Miss D. A. E. Garrod, Prof. W. J. Sollas, Mr. Mark L. Sykes. **£10.**

To conduct Anthropological investigations in some Oxfordshire villages.—Mr. H. J. E. Peake (*Chairman*), Mr. L. H. Dudley Buxton (*Secretary*), Dr. Vaughan Cornish, Miss R. M. Fleming, Prof. F. G. Parsons.

To report on the present state of knowledge of the relation of early Palæolithic Implements to Glacial Deposits.—Mr. H. J. E. Peake (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Mr. H. Balfour, Prof. P. G. H. Boswell, Mr. M. Burkitt, Prof. J. E. Marr.

To co-operate with a Committee of the Royal Anthropological Institute in the exploration of Caves in the Derbyshire district.—Mr. M. Burkitt (*Chairman*), Mr. G. A. Garfitt (*Secretary*), Mr. A. Leslie Armstrong, Prof. P. G. H. Boswell, Mr. E. N. Fallaize, Dr. R. V. Favell, Prof. H. J. Fleure, Miss D. A. E. Garrod, Dr. A. C. Haddon, Mr. Wilfrid Jackson, Dr. L. S. Palmer, Prof. F. G. Parsons, Mr. H. J. E. Peake. **£25**.

To investigate processes of Growth in Children, with a view to discovering Differences due to Race and Sex, and further to study Racial Differences in Women.—Sir A. Keith (*Chairman*), Prof. H. J. Fleure (*Secretary*), Mr. L. H. Dudley Buxton, Dr. A. Low, Prof. F. G. Parsons, Dr. F. C. Shrubsall.

To report on proposals for an Anthropological and Archæological Bibliography, with power to co-operate with other bodies.—Dr. A. C. Haddon (*Chairman*), Mr. E. N. Fallaize (*Secretary*), Dr. T. Ashby, Mr. W. H. Barker, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Prof. J. L. Myres, Mr. H. J. E. Peake, Dr. D. Randall-MacIver, Mr. T. Sheppard.

To report on the progress of Anthropological Teaching in the present century.—Dr. A. C. Haddon (*Chairman*), Prof. J. L. Myres (*Secretary*), Prof. H. J. Fleure, Dr. R. R. Marett, Prof. C. G. Seligman.

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THE PRESIDENTIAL ADDRESS.

CRAFTSMANSHIP AND SCIENCE.

BY

PROFESSOR SIR WILLIAM BRAGG, K.B.E., D.Sc., D.C.L., LL.D., F.R.S.,

PRESIDENT OF THE ASSOCIATION.

Down House: Errata.

Page xlvii, line 25, *for* 'Perrero' *read* 'Terrero.'
Page xlviii, line 11, *for* 'Vines' *read* 'Viner.'
Page xlix, line 19, *for* 'Wedgewood' *read* 'Wedgwood.'

justification for doing so the fact that in the last few years scientific inquiry has advanced at a rate which to all is amazing, and to some is even alarming. On the one hand, the application of science to industry has become increasingly important and obvious, as was so clearly shown by our honoured President of two years ago. Especially at the present time when our country is struggling to free itself from distress due partly to the war and partly to violent changes in economic conditions is it of interest and importance to consider what science is doing and can do to accelerate recovery. On the other hand, in the less material realms the applications of recent research have aroused wide interest, as may be exemplified by the influence on philosophic thought of the new discoveries in physical science, or by the effect of last year's remarkable Address from this chair.

I cannot deal in the time allotted to me with all the issues that are suggested by these considerations. I propose to limit myself in a manner which my choice of title will suggest, and in speaking of 'craftsmanship and science' to pay attention more particularly to the relations between science and the craftsmanship of our own country. I shall not, however,

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WHEN, nearly a century ago, the founders of our Association drew up a statement of purposes and rules they gave prominence to the words 'to obtain more general attention for the objects of Science.' Since that time we have tried continuously to fulfil our self-imposed task, not, I hope, unwisely nor untactfully, nor without success. For this purpose we have on many occasions and in many ways endeavoured to describe the progress of our researches, and to present the consequences of discoveries as they appeared to the discoverers. With your permission, I would like this evening to add something to the story. I would claim as my justification for doing so the fact that in the last few years scientific inquiry has advanced at a rate which to all is amazing, and to some is even alarming. On the one hand, the application of science to industry has become increasingly important and obvious, as was so clearly shown by our honoured President of two years ago. Especially at the present time when our country is struggling to free itself from distress due partly to the war and partly to violent changes in economic conditions is it of interest and importance to consider what science is doing and can do to accelerate recovery. On the other hand, in the less material realms the applications of recent research have aroused wide interest, as may be exemplified by the influence on philosophic thought of the new discoveries in physical science, or by the effect of last year's remarkable Address from this chair.

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be able to confine myself strictly within these limits because the entrance of science into our most material businesses cannot be considered without reference to the part that science plays in the whole range of our thoughts and actions.

The term craftsmanship requires definition. I am supposing it to mean the skill which is exercised in the production of whatever is wanted for human welfare. Imagine an island so cut off from the rest of the world that its inhabitants must depend on themselves for the satisfaction of all their desires, for their food, even if they have no more to do than pick fruit from a tree, for their clothing, for their housing, and other material things. They must also find their own means of satisfying less material cravings : for if they have intelligence they will look for means of studying themselves, their neighbours and the world round about them. Their eyes and ears will ask to be used for the satisfaction of a sense of beauty in form and colour and sound, and their minds will try to reach out beyond what can be seen and heard. It is impossible to proceed to the satisfaction of these desires without the handling of materials, and craftsmanship begins with the skill exercised in the handling.

What the islanders succeed in achieving by their craftsmanship may justly be described as their wages, they being their own employers. If their wages are to be raised they must somehow increase one or more of the factors on which their success depends. They must be more diligent in the discovery of materials for which a use can be found ; they must become better acquainted with the properties of those materials; they must develop their constructive skill. If they are too primitive to have developed the use of mechanical power they must do everything with their own hands, guided by their own intelligence and their own feeling for what is beautiful and fitting. At every step enter the qualities that go to make craftsmanship, as I would interpret the term. There is knowledge of materials, there is imagination, there is technical skill ; perseverance is wanted, love of the work itself, sympathy with the use that is to be made of it, and with the user. Clearly, on the craftsmanship of the islanders will depend whether they have enough food to go round, enough clothes to wear, whether they have leisure for anything beyond the labour that satisfies their barest necessities.

And, of course, this isolated group of people will have some characteristic estimation of what kind of wages they want. Their energies may conceivably be devoted only to the production of things that satisfy bodily desires, or they may be bent also on nobler things. I need not

consider that point as I am not trying to picture Utopia. All that this image is meant to convey is the idea of craftsmanship and its fundamental importance. Nor is the account yet complete; far from it. It is not only that the products of craftsmanship are a necessity if the islanders are to live at all: craftsmanship has a value in itself. There is in men, more in some, less in others, the natural desire to use what faculties they possess. It is a fact that love of good work and delight in successful accomplishment are powerful motives, and when satisfied are sources of real happiness. Of all the motives that sway the world these are among the purest and best.

The power to produce in plenty what is wanted is, of course, only one of the great problems that a community has to consider. There is also the endlessly difficult question of distribution, of the manner in which each working individual is to receive his share of the wages. The two problems cannot be separated entirely: the means directed to the solution of one contribute to the solution of the other. But I must not attempt too much: science is in the first instance concerned with the production problem; the distribution problem follows.

Let us extend our image a little; let our island be discovered and put into communication with the outside world. An exchange of craft work sets in: the islanders discover new wants that must be satisfied and they pay for the necessary imports by exporting what they make themselves. But the exports must be made to satisfy the tastes of the outside peoples or there will be no trade. So the islanders now find that they must no longer consider their own tastes entirely: they must accommodate themselves to a more general conception which is only in part their own. It may happen that under the new conditions they become less and less self-contained. Some things which are necessary to life, such as food or clothing, may become imports, being no longer produced, at any rate in sufficient quantity, within the island itself. And now the people are very firmly tied to the rest of the world; they must give that they may receive, and they must please in order that others may be willing to take. We may say that their craftsmanship is now judged more critically; and more than ever it becomes fundamental to well-being, even to existence. The conclusion I would draw from this very simple little analogy is that a people lives on what it makes or earns and that its success depends on its craftsmanship. A people cannot expect to be provided for: it has no rights.

I would ask you presently to consider the difference between the craftsmanship of an early civilization and that of our own more com-

plicated times. But before doing so, let me say yet one or two words about the older forms.

We have a profound feeling for any example of an old craft, and for very good reasons. Among them I do not include the sentimental regret that, in some cases, a past time skill seems to have disappeared. We may be sorry, but after all it is but a receipt that has been lost and may be found again any day, if proper search is made for it. Modern knowledge and methods of analysis are at least good for that much. Nor is the collector's pride of rarity the worthiest feeling that the old specimen inspires.

Our affection for it, and the reverential care with which we handle it are due to the fact that it represents to us the labour of a people, labour into which knowledge, imagination, love of beauty, technical skill have all entered. The most of what was once used in every-day life has long disappeared; even such more durable things as houses and ships, roads and cultivations may have ceased to be. The few objects that survive must be taken as examples of what has been lost. And on the showing of the student a spirit will emerge from an old vessel as great as that which issued when the fisherman of the Arabian Nights unsealed the pot that had long been lying at the bottom of the river. It is the spirit of the bygone people that takes shape before us.

The Greek gave exquisite form to his vase and decorated its surface with equal art. He copied from the growing things of Nature the adjustment of lines and surfaces which give the sense of fitness for a purpose. The outlines of his vases are so perfectly adjusted that their representation in a drawing will not bear alteration by the width of a line. That the Greek should with so much skill take lessons from what his perception made clear to him, and should with so much care choose his materials and mould them to his purpose is what we should expect from a nation that shows also in its literature a passion for justice and harmony. The fine accuracy of his line is in agreement with his delicate sense of differences in thought and words.

The Roman developed the principle of the arch, and enough remains of what he built to show the daring and the power of his work. The great arches that spanned his public buildings seem to stand for the Roman rule and law under which the whole world might find shelter and be at peace.

The sword of the Indian workman was gradually brought to its temper by an infinite series of local applications of heat alternating with the few

blows that could be skilfully given while for a moment it was in the workable state. The poverty of the craftsman's appliances, the meagreness of his little fire and the scantiness of the tools with which he made his way bit by bit to his final achievement are in consonance with his life of small details ruled by overmastering ideas.

I need not illustrate further. It is indeed well known to you all that the craftsmanship of a people is an expression of the best of its very self. It is to the underlying reason that I would draw your attention now. The mind of a nation is so expressed because its craftsmanship, interpreted in its widest sense, represents its efforts to live. Under this strong compulsion the nation produces results which range from pots to poetry, and all its products are stamped alike. That which we do ourselves is as representative as a Greek vase or a Roman aqueduct or a suit of armour from Milan. The craftsmanship of a nation is its very life. Even if we consider it only in relation to the production of material things, the state of a nation's craftsmanship is an index of its health.

As a people departs from its primitive condition so also does its craftsmanship. I would ask you to consider the nature of the change. The elements of craftsmanship in its original form centre round the individual. In his brain is the knowledge and imagination, in his hands is the skill, and round about him lie the materials and the tools of his craft. But as the years go by it becomes impossible that all the knowledge and all the technical skill should be found in one person, and all the tools be owned by him. The craftsman becomes an association of men, a great manufacturing firm, even, we might say, a nation, if all the members of the nation contribute through Government intervention and control to the maintenance of some industry. Many hands, working in an alliance which is often unconscious, are employed in bringing a product to its finished form. It is a long step from the simple workshop of the old single-handed craftsman to the vast complex factory of modern industry.

If now we ask ourselves what has brought us to this new kind of modern craftsmanship, this dependence on machinery with its wealth of production, its clattering, bustling activity, and its compelling influence on the lives of all of us, we find that one simple cause has been continuously operative. It is nothing more nor less than the urgent wish of the individual to better his own condition : and, in his disinterested moods, the condition of his neighbours. The change could never have been prevented.

When Hargreaves thought that by a mechanical arrangement he could manipulate several spinning wheels at one time, and succeeded, so that he

had more wages to spend on his wife and children, he was obeying a universal and natural impulse. Hargreaves' neighbours being left behind in the competition for wages, pulled his house about his ears. But in the end, they, too, found themselves to be turning many spinning wheels where formerly they had only handled one. Then they, too, had more money to spend. What other turn could things have taken under the circumstances? What happened in this isolated incident is repeated again and again in every craft, and in sequence change and change marks the road that stretches far from its beginnings.

Quite apart from all considerations as to whether the new is better or worse than the old, more beautiful or less beautiful, whether it calls out the best in man as well as the older ways, or whether it fails to do so, apart from all comparisons of this kind stands the fact that the change is due to natural impulses which will not be gainsaid. The results have to be accepted. We cannot put the clock back. We cannot, let us say, wipe away the great steelworks of the world and replace them by thousands of individuals each with his single anvil and single hammer. We cannot replace the great ships of Glasgow by a multitude of little sailing boats. The plain truth is that modern craftsmanship with all its noise and ugliness is giving food and clothing, warmth and interest to millions who otherwise must die. It is ungrateful to find fault except with sympathy. Let us try in all possible ways to mend its offences and soften its hardships, but in all honesty let us recognise that we live on modern craftsmanship in its modern form. We are each and every one of us responsible for the present conditions as long as we insist on spending money to the best advantage.

At this point it is convenient to refer to a matter which would be of little importance if it did not seem sometimes to put modern craftsmanship in a wrong light. We are continually discovering instances of the marvellous skill of the craftsman of thousands of years ago. There is here, however, no disheartening implication, as has sometimes been asserted, that men can no longer do what was once in their power. To those who look into what goes on in a factory or a mine, in the field or on the sea, there are innumerable instances of beautiful craft work, beautiful because of their fitness for their purpose, their balance of design, their ingenuity, their history, their growth under human perseverance and thought. Every one of us can bring to mind instances of technical skill demanding imagination and intelligence as well as manipulative power which could be set alongside any instance in history. Let me name only

one: could anything surpass the drawing of fibres of quartz, finer by far than a human hair, by means of the bow and arrow? It was a feat to imagine that it could be done, to anticipate that when done it would fill so perfectly an urgent need in the construction of many important instruments, and finally, to do it.

Now we come to the point at which I would ask you to consider the relation of science to the craftsmanship which I have been trying to define. I would draw your attention to the manner in which, under the urgent drive of self-preservation, the craftsman has called scientific knowledge to his aid. Sometimes the moment has been dramatic on account of the great need of the occasion and the prompt effectiveness of the reply. When, for example, coalmining was at a low ebb because the mines were becoming waterlogged and no available power was strong enough to clear them, Savery and Newcomen made use of the new discoveries respecting the pressures of gases and vapours which Torricelli and Pascal, Papin and Hooke, had just been examining and trying to explain. The steam engine thus came into being and saved the situation. And when, at a somewhat later date, your own citizen, James Watt, by further application of the same physical laws, added fresh powers to the engine, the modern steam engine came into view, with all its applications to railways and steamships and many other marvels of to-day. In 1831 Faraday, in the course of certain systematic searchings, found out the way in which one electric current could bring another into being, the so-called electromagnetic induction. With that single day's work began the whole development of electrical engineering in its innumerable forms. I need not increase the number of my illustrations.

More often it happens that scientific knowledge enters with less instantaneous and startling effect into the history of a craft. It is only when you come to consider the various details of some modern product of craftsmanship that you suddenly realise how closely every detail is connected with the advance of science, and indeed, to be more particular, with the scientific laboratory. Let us think for a moment of one of those magnificent ships for which the Clyde is famous. Let us survey its various parts in our minds. Its hull of steel recalls the great forges of Britain, and the wealth of research that has been spent in works and metallurgical laboratories on the nature and qualities of steels of all kinds, research which is still in progress. Within are the engines, turbines perhaps, or reciprocating, or it may be internal combustion engines, Diesel or others. What a range of inquiry and trial and development lies in every detail,

depending always on principles of physical and chemical science, tested at every stage by instruments which are a craft in themselves! You may think of the screw and of its design. You picture the curious and most efficient thrust-block by which the force of the screw is brought to bear upon the ship, and remember that Michell lately designed it on the basis of the physical laws of liquids. You look aloft and see the wireless and are reminded that this sprang directly from the physical laboratory. Your sounding apparatus is based on your own Kelvin's designs; it may be that you have fitted your ship with the wonderful and still more recent apparatus for sounding by echo, which enables her to find the depth of water, shallow or deep, even when she is travelling at high speed. The war forced this adaptation of the laws of acoustics. She is sure to carry some form of refrigerating apparatus, and now we are reminded of all the investigations into the production of cold by students of science like the Frenchmen Cailletet and Pictet, by Onnes in Holland, and by Dewar, whom, as befits the occasion, I will call a Scotsman rather than an Englishman. And so on, from one great feature of the ship to another, and presently from detail to detail; and you find that the whole structure is linked by innumerable ties to the research work of the laboratories. Craftsmanship in its urgent need has called upon scientific knowledge for aid, and the mighty growth is due to the response. Indeed, it is not only craftsmanship that has grown, but science itself.

If you hinder the growth of science in any way you hinder the growth of craftsmanship. Now it is an important fact that science advances over a wide front, and the various branches of it move on together: not absolutely keeping step with each other, but preserving a general line. It has been suggested that science might refrain from development in some directions or, even as our good friend the Bishop of Ripon said at Leeds last year, we might proclaim a ten years' holiday. But you cannot prevent interested men from making inquiry. You cannot prevent the growth of knowledge, you cannot even make a selection of those points of advance which will lead to certain select classes of results. No one knows what is over the hill. The vanguard moves on without any thought of what is before it. That is why, if the march of science is to be conducted in an effective and orderly way, were it only for the purposes of industry, there must always be a certain number of laboratories or parts of laboratories where scientific research has no immediate thought of possible applications.

If I read modern industrial conditions rightly the closeness of the

connection between craftsmanship and science may be illustrated in yet another way. It is, I think, a fact, and a remarkable fact, that the most active of our modern industries are those which are founded on recent scientific research. The most notable is, of course, that of electrical engineering. The year that sees the celebration of our Association's centenary will witness also the ceremonies that commemorate the basic experiment of Faraday. It is difficult to sketch in a few words the great edifices that have been built upon the discovery of electromagnetic induction. We might look upon it financially and picture, as some of my hearers can do, the amount of capital involved in electrical undertakings throughout the world, electric lighting, electric transmission of power, cables and now wireless, not to mention all the minor uses to which electricity is put. The transference of matter, of intelligence, of thought, of sound, even of vision, is largely dependent on electromagnetic action. If we are not familiar with financial quantities, let us just think for a moment of the change in our lives if every electric current ceased to run; and let us realise that the whole mechanism of modern intercourse would fail and that populations born to use it would be brought to dire distress.

Though the electrical engineering industry with all its branches may be said to have its source in a single laboratory experiment, yet it has grown by the continuous adaptation of fresh streams of knowledge. The huge American corporations maintain research laboratories costing millions of pounds annually, and find that the financial return justifies their policy. The General Electric Company found that a costly research into the structure of the electric lamp repaid itself over and over again. The very important technical discoveries of Langmuir and Coolidge were consequent upon an attempt to find out what happened on the surfaces of the glass bulb and of the glowing filament. The point is that the electrical industry was not merely launched by a single discovery; it is continually guided, strengthened and extended by unremitting research.

Consider the very active motor industry. The most important of all the problems connected with the internal combustion engine is that of the nature of the explosion, the effects of varying the mixture, the movement of the gas in the cylinder before the ignition, the actual occurrences at the moment of ignition, the movement of the subsequent explosion wave. The problems are exceedingly intricate. They have been and are the subject of intense research in various laboratories in this country. The research is new and the industry is new. The construction of the engine depends on the use of alloys possessing the most remarkable

properties, all of which were practically unknown until recent researches of the metallurgists brought them to light. The motor car is connected, too, with the laboratories in which chemistry and physics are applied to the study of rubber. Here again is a whole story in itself, which would tell of the work done on the intricate consequences of various kinds of mixings and of treatment, of the vulcanising and of the use of 'fillers.' Not many know the story; they are only aware that motor car tyres last longer than was once the case.

The aeroplane, like the motor car, has become possible because of the advent of the internal combustion engine; but it has a unique feature—its element of romance, its motion through the air. The laws of aerodynamics are becoming better known, and with every advance in their knowledge the efficiency of the aeroplane increases. Their intricacy is gradually resolved, but the process demands, in the first place, mathematical skill, and in the second the fascinating research that is carried on in the wind channels of our laboratories. On this splendid work the progress of the aeroplane depends. I saw not long ago in a London shop window a coloured print of a flying machine. From across the street it might easily have been taken for a drawing of a modern aeroplane; a closer view showed still the same general spread of wings, the same whirling screws, the same discharge from the exhaust, a boat not at all untrue to modern design, and wheels to bear it when on land. Moreover the proportions were quite familiar. Yet the date was 1843. For all its resemblance to the modern aeroplane, how far it was from flying not only in time but in capacity! The difference between old and new in the form and materials of the wings may not be obvious to the casual observer, but in reality a wealth of trial and calculation lies between the crude projections of the old invention and the modern machine that flies. The turn of a line in the sectional outline of the wing may make the difference between success and failure, though it is only one of innumerable and equally essential details. The scientific worker grasps the meaning of that turn, and the airman tries it out, and that is the combination which brings success at last. The point is that the construction of the flying machine is a new industry based directly on knowledge recently acquired in the laboratories and continually growing under laboratory experiment. Everything depends on this careful, well-informed concentration on essential details.

If we enter the chemical province we find that there are thriving industries based on recent scientific discovery; instances at least as

remarkable as those possessing a more physical basis. The chemical industries are so many and various that even a brief summary is beyond me; yet the whole of them are of comparatively recent origin. Quantitative chemistry is little more than a century old. And the more modern and more vigorous of the chemical industries depend on very recent chemical research, as, for example, those which deal with dyes, explosives, fertilisers, rubber, artificial silk and many other things. It is the same story: the craft is based on science, and in this case very obviously so. Chemical industries are based on scientific discovery, and lean on it the whole time.

It is natural to compare the condition of the newer industries with the older industries known as basic because they have long constituted by far the major portion of the country's industrial effort and are still pre-eminent: coal and steel, cotton and wool. In some of these industries there is serious depression. What has the fact to do with science and scientific research?

It is obvious that we cannot say of any industry or craft that its condition depends only on scientific knowledge and imagination. The difficulties of the coal trade are due in large part to the powerful cause of competition. We had a good start in the knowledge of the existence of our coal deposits and in the practice of working them, in the means of distributing coal and in methods of making use of it. We reaped our harvest. But as time went on other nations gathered way in pursuit of us; they also found coal deposits, they learnt how to work them and could even improve on our practice because they could profit by our mistakes to a greater extent than we ourselves. They had not so much old machinery to scrap. Means of transit were developed in these countries; in fact we helped to develop them, as also the industries that used the coal. Such conditions must inevitably have tended to diminish our lead. The war acted suddenly and violently in the same direction. It is reasonable, though deplorable, that the industry should find itself in difficulties. The situation is not wholly irremediable, though the older conditions can never completely return. But at least a partial retrievement is possible, and we know that various research organisations, some instituted by the State and some due to private enterprise, are grappling with the question involved. It is deeply interesting to see in what way the necessary efforts are being made, and indeed must be made.

Now, whatever is done, and in whatever way it is done, the results of such endeavour, whether related to the coal or to any other industry,

depend on those relations between craftsmanship and science which I have been trying to define. I would now consider these relations from one or two separate points of view. In the first instance let me say a word concerning the general connection between science and that condition in industry which is known as mass production.

It must always be the aim of an industrial organisation to devise and set going one of those systems of manufacture on a large scale with which we have become familiar in recent years. With the aid of suitably designed machinery and methods, great numbers or quantities of some article in general demand can be produced at a comparatively small running cost. Generally, however, the initial cost is heavy, for the designing of the machinery and the planning of the methods call for great experience and skill, and they demand much time spent in the acquirement of the necessary knowledge and its utilisation in design. Once the process is under way it may be possible, and it seems to happen on a sufficiently attractive number of occasions, that a smooth and peaceful running of the machinery brings in the wished-for returns. But every such phase of production comes to a natural end. An improved process is devised, and the new displaces the old. Or it may be a factory is set up in another country where labourers can be hired more cheaply; they may be intrinsically inferior, but that will not matter if they can be drilled into the mechanical process; and, as long as the machine runs true, the standard will not fall below a certain value. The event is in accord with expectation because men will always try to improve their productivity by the use of new knowledge or more favourable conditions, so that those who fail to recognise the principle will be left behind by those who do not. The stereotyping of some process can only be fruitful for its allotted time. Mass production is in its way splendid, ministering to the necessities and conveniences of many who must otherwise have gone without. But, if it is brought to such a pitch that its processes call for little intelligence in their working, then cheap people of little intelligence will be found, in the end, to be in charge.

The relation of science to mass production is therefore both that of builder and that of destroyer. Mass productions are temporary lulls in the movement of imagination and knowledge. Much skill and thought and care may be required to arrange for one of those quiet and profitable times; the machine is set going and for a while goes by itself. But new applications of scientific knowledge, new ideas, new processes, new machines must always be in preparation. In the parks the gardeners are always

nursing fresh plants to take the place of the old, and preparing them for their useful time of flowering. And so we see the meaning of the various research organisations which have been set up in the basic industries, such as the Fuel Research Board, the Cotton, the Woollen and the Silk Research Associations, the research laboratories of the steel masters at Sheffield. Much of our hope for the future is built upon their work.

If craftsmanship, to fulfil its task of providing for the people, must be continually improving its processes, then the nation that is to be successful must possess the means and the will to improve, and here we come, I think, to a notable point. May it not be said that in this country the means exist even to a remarkable degree ? Our craftsmen as a whole, including all grades, are possessed of qualities, intelligence, skill, accuracy, and so on, which make improvement possible. How could our enterprises in the past have been so often successful if this had not been so ? How can we be succeeding so well in respect to the new industries of the present if the capacity is not there ?

Should it not, therefore, be our policy to take advantage of our country's qualities by continually seeking for fresh industries or fresh adaptations of the old ? We should not surely cling unduly to older activities when they have reached the stage in which many others have learnt to do them with equal efficiency, and when we can go on to something new and, it may be, more difficult. We can, of course, bolster up old industries by political methods, and I have no wish to decry such methods as always incorrect. But clearly the best protection of all is the knowledge and skill which can enable us to produce what others must ask us for because they cannot so well make it themselves.

These considerations lead naturally to a second aspect of the relations between craftsmanship and science. The improvement of craftsmanship depends in large part on the absorption and adaptation of scientific discovery. How is the process to be encouraged ?

We here come to a point which must be emphasised with all possible vigour, because its importance is not always realised. Scientific knowledge and experience if it is to be of full service must be in direct practical contact with the problem that is to be solved. This must be clear to every one of us from actual experience. If you have expert knowledge on any subject and your advice is asked, your first instinct is, as you all know, to ask to be allowed to see for yourself. It is only when all the circumstances are clear to you in their relation to the difficulty that the solution is likely to suggest itself. And it may take much watching and patient

observation before you are successful. It is the combination of actual experience with scientific knowledge that is essential. As the principle is so fundamental, I may be allowed to illustrate it by an actual experience :—

It was in the early years of the war that a body of young scientific students from our Universities was assembled for the purpose of testing on the battlefield the value of such methods of locating enemy guns as were already known. In their mutual discussions and considerations it became clear to them that the great desideratum was a method of measuring very exactly the time of arrival of the air pulse, due to the discharge of the gun, at various stations in their own lines. If the relative positions of the stations were accurately known it would then become a matter of calculation to find the gun position. But the pulse was very feeble : how could it be registered ? Various methods were considered, and among them was one which no doubt seemed far-fetched and unlikely to be successful. A fine wire is made to carry an electric current by which it is heated. If it is chilled, for example, by a puff of cold air, the resistance to the passage of the current increases, and this is an effect which can be measured if it is large enough. If, then, the hot wire could be made to register the arrival of the air pulse from the gun a solution of the problem was in hand. No doubt this method occurred to several members of the company ; it was certainly turned over in the mind of one of them who had had considerable experience of these fine heated wires. They had been in use about thirty years, having been employed for the measurement of temperature in many circumstances where their peculiar characteristics gave them the supremacy over thermometers of the ordinary form. But, and this was the important point, was it to be expected that the effect, though it must be there, would be big enough to see ? Could the faint impulse from a gun miles away produce an obvious chill in a hot wire ? On first thoughts it did not seem likely, and the suggestion lay in abeyance.

But it happened that one summer morning an enemy aeroplane came over at daybreak on a patrolling expedition. The officer of whom I have spoken lay awake in his bunk listening to the discharges of the anti-aircraft guns and the more distant explosions of their shells. Every now and then a faint whistling sound seemed to be connected with the louder sounds. The wall of the hut was of felt ; it was in poor condition and there were tiny rents close to his head as he lay. The gun pulses made a feeble sound as they came through. This set the officer thinking : if the pulse was strong enough to make a sound, it might be strong enough to chill a hot wire perceptibly. So the method was

proposed to the company as worth trying. It was tried, and proved to be a complete success. The sound ranging of the British armies was based upon it, with results which have already been described and are fairly well known.

It is clear that the all-important suggestion could only have been made by a man who had had scientific training and experience. That is one point of the first significance. The second is that it could only have been made by such a man actually on the spot. He could not have realised the details of the problem if he had been anywhere else.

It is worth while to consider this last point a little more closely. What precisely was the difficulty which could only be resolved by a combination of knowledge and of being on the spot? It was really the difficulty of making a true estimation of quantities. It was a question of magnitudes and measurements. Anyone possessed of scientific knowledge could have said, if asked, that a gun must make an air pulse, and that an air pulse would chill a hot wire to an extent which might or might not be measurable. But there is all the difference in the world between such vague general knowledge on the one hand, and, on the other, the realisation that such a method is likely to work and give the desired result. It is the difference which so often escapes attention, but everyone of experience knows that it is to be reckoned among the essentials. It is so easy to talk generalities or to think of them, and so difficult to get down to the details which make the effort a success. It may be the last little adjustment of magnitudes that turns the scale, and the last step the one that counts.

Are we, then, in this country, putting our scientific knowledge into the position where it is really effective? I would draw your attention to a most interesting and important movement which is attaining a notable magnitude.

A new class of worker is growing up among us consisting of the men engaged in research associations and industrial research laboratories throughout the country. We must place a high value on their services, for they are actually and personally bringing back with them into craftsmanship the scientific knowledge which is one of its essentials. They bring the interest and the outlook of scientific inquiry into touch with both employer and employed, and I cannot but think that they may be to some extent the flux that will make them run together. For they can speak with the employer as men also trained in University and College, exchanging thought with ease and accuracy. And, at the same time, they are fellow workers with those in the shops and can bring back there

some of the interest and enthusiasm which springs from the understanding of purposes and methods. It is to be remembered always that personal contact has, on the whole, thanks to the better qualities in human nature, a marvellous effect in smoothing out differences. I do not think it is unduly optimistic to welcome the growth of this new type of industrial worker because it can, being in personal intercourse with both capital and labour, supply to each a new outlook on their whole enterprise, especially as that outlook is naturally illuminating and suggestive. For, after all, this is but going back to first conditions. The primitive craftsman has been replaced by separate persons or groups of persons who have slipped away from each other almost without our realising the fact. In the most recent times the separation has become more obvious and more dangerous, and that is why in so many directions efforts are being made to stem it. Can it be good that the workman has a part demanding little intelligence, merely the capacity to repeat? Can it be expedient that mere manipulation should be left in the shop, while design and imagination have gone into the drawing office and shut the door behind them? Can it be right that the factory directorate should not be in immediate contact with the vast body of scientific knowledge?

The present number of industrial research workers is relatively small; it seems likely to increase, however, in proportion to the extent to which the province of science is better understood. The better understanding I think of as manifesting in the first place in industry itself. I am sure that here it is happily on the increase. There is also a broader view to be taken. There is a public estimation of the value of any calling which affects the numbers and the quality of those who respond.

I doubt if there is in the first place sufficient appreciation of the interests and rewards in the life of a student of industrial research. The pioneers have suffered unnecessary restrictions and discouragements, but their followers will be in better case. Surely it does not need much imagination to realise the splendid side of such work? The succession of fresh difficulties to be overcome, and of new and interesting views into the nature of things and ways of the world; the unforeseen value of results, sometimes an immediate prize, sometimes the clearing of an obstacle in a manufacturing process, never less than the discovery of facts which may some day be of use; the personal association with a living enterprise and with the human spirit behind it. And when it is realised that this kind of work is wanted badly, that it is really serviceable to the community, that there is opportunity for devotion, that it is in touch at once with

human needs and with the furthest stretches of thought and imagination, it surely takes on to us the final touch of nobility.

We must remember also that the road of the student of science is still none too clear. The very methods of teaching science are a constant subject of discussion. I will say no more now than this: that the best methods must take time to elaborate, and cannot be expected to have arrived at their final form. The difficulty is increased by the fact that science itself grows rapidly, and the extent of its application is only now revealing itself. That the knowledge of the immensity of nature and the study of the natural laws have an educative value is well recognised. That science can be used as an educational drill is also known and made use of. But there still remains the human side; the continuous effect of the growth of knowledge upon thought and enterprise; the realisation of the immense part that science is playing in modern life and is likely to go on playing. Education by scientific instruction is still apt to lack the comprehension of the human side, without which the classroom is a dull place.

There are even some who think that science is inhuman. They speak or write as if students of modern science would destroy reverence and faith. I do not know how that can be said of the student who stands daily in the presence of what seems to him to be infinite. Let us look at this point a little more closely.

The growth of knowledge never makes an old craft seem poor and negligible. On the contrary it often happens that under new light it grows in our interest and respect. Science lives on experiment; and if a tool or a process has gradually taken shape from the experience of centuries, science seizes on the results as those of an experiment of special value. She is not so foolish as to throw away that in which the slowly gathered wisdom of ages is stored. In this she is a conservative of conservatives.

What is true of a tool or process is true also of those formulæ in which growing science has tried to describe her discoveries. A new discovery seems at first sight to make an old hypothesis or definition become obsolete. The words cannot be stretched to cover a wider meaning. By no means, however, is that which is old to be thrown away; it has been the best possible attempt to express what was understood at the time when it was formed. The new is to be preferred for its better ability to contain the results of a wider experience. But in its time it will also be put aside. It is by a series of successive steps that we approach the truth: each step reached with the help of that which preceded it.

Nothing in the progress of science, and more particularly of modern science, is so impressive as the growing appreciation of the immensity of what awaits discovery, and the contrasted feebleness of our ability to put into words even so much as we already dimly apprehend. Let me take an example from the world of the physical sciences. There is a problem of which the minds of physicists have been full in recent years. The nineteenth-century theory of radiation asks us to look on light as a series of waves in an all-pervading ether. The theory has been marvellously successful, and the great advances of nineteenth-century physics were largely based upon it. It can satisfy the fundamental test of all theories, for it can predict the occurrence of effects which can be tested by experiment and found to be correct. There is no question of its truth in the ordinary sense.

In the last twenty or thirty years a vast new field of optical research has been opened up, and among the curious things we have found is the fact that light has the properties of a stream of very minute particles. Only on that hypothesis can many experimental facts be explained. A wave theory is of no use in the newer field. How are the two views to be reconciled ? How can anything be at once a wave and a particle ? I do not believe that I am unjust to any existing thinker if I say that no one yet has bridged the gap. Some of you who were present at the Liverpool meeting may remember that Bohr—one of the leading physicists of the world—doubted if the human mind was yet sufficiently developed to the stage in which it would be able to grasp the whole explanation. It may be a step forward to say, as we have been saying vaguely for some years, that both theories are true, that there are corpuscles and there are waves and that the former are actually responsible for the transference of energy in light and heat, and for making us see ; while the latter guide the former on their way. This is going back to Newton, who expressed ideas of this kind in his 'Opticks,' though he was careful to add that they were no more than a suggestion.

We are here face to face with a strange problem. We know that there must be a reconcilement of our contradictory experiments ; it is surely our conceptions of the truth which are at fault, though each conception seems valid and proved. There must be a truth which is greater than any of our descriptions of it. Here is an actual case where the human mind is brought face to face with its own defects. What can we do ? What do we do ? As physicists we use either hypothesis according to the range of experiences that we wish to consider. To repeat a phrase

which I employed a few years ago in addressing a University audience familiar with lecture time-tables, on Mondays, Wednesdays and Fridays we adopt the one hypothesis, on Tuesdays, Thursdays and Saturdays the other. We know that we cannot be seeing clearly and fully in either case, but are perfectly content to work and wait for the complete understanding.

And when we look back over the two centuries or so during which scientific men have tried systematically to solve the riddle of light, or even go further back to the surmisings of philosophers of still older time, we see that every conscientious attempt has made some approach to the goal. The theories of one time are supplanted by those of a succeeding time, and those again yield to something more like the first. But it is no idle series of changes, no vagaries of whimsical fashion ; it is growth. The older never becomes invalid, and the new respects the old because that is the case.

Surely it is the same in regard to less material affairs. The scientific worker is the last man in the world to throw away hastily an old faith or convention or to think that discovery must bring contempt on tradition.

There is a curious parallelism here to a relation between science and industry of which I have already spoken. Just as any particular case of mass production can be regarded as a temporary condition which the growth of knowledge brings about, and in the end supersedes, so also it may be said of any law or rule or convention or definition that knowledge is both the parent and eventually the destroyer. Time devours his own children. Even if a statement retains its outward form, its contents change with the meanings attached to its terms : and change moreover in different directions when used by different people, so that constant re-definition is necessary. How much more is this the case when the contents themselves have to be added to. The distinction between truth itself and attempts to embody it in words is so constantly forced upon the student of science as to give his statements on all matters a characteristic form and expression. And this is, I think, one of the reasons why men are often needlessly alarmed by the new announcements of science and think they are subversive of that which has been proved by time.

To this consideration I may add yet one more, which may be illustrated by the same analogy. Scientific research in the laboratory is based on simple relations between cause and effect in the natural world. These have at times been adopted, many of us would say wrongly, as the main principle of a mechanistic theory of the universe. That relation holds in

our experimental work ; and as long as it does so we avail ourselves of it, necessarily and with right. But just as in the case of research into the properties of radiation we use a corpuscular theory or a wave theory according to the needs of the moment, the two theories being actually incompatible to our minds in their present development, so the use of a mechanistic theory in the laboratory does not imply that it represents all that the human mind can use or grasp on other occasions, in present or in future times.

The proper employment of scientific research is so necessary to our welfare that we cannot afford to allow misconceptions to hinder it ; and the worst of all are those which would suppose it to contradict the highest aims. Science, as a young friend said to me not long ago, is not setting forth to destroy the soul of the nation, but to keep body and soul together.

And some perhaps might say that in considering science in relation to craftsmanship I am pressing the less noble view ; that I am not considering knowledge as its own end. It is said that uselessness in science is a virtue. The accusation is a little obscure because it may justly be said that knowledge is never useless. If I have thought of science in relation to craftsmanship it is because I have tried to set out the vast importance of what craftsmanship means and stands for. I have not forgotten that there are other aspects of the inquiry into the truths of Nature. Indeed, I could not carry out the lesser task without considering the whole meaning of science. And no clear line can be drawn between pure science and applied science : they are but two stages of development, two phases which melt into one another, and either loses virtue if dissociated from the other. The dual relation is common to many human activities and has been expressed in many ways. Long ago it was said in terms which in their comprehensiveness include all the aspirations of the searcher after knowledge : 'Thou shalt love the Lord thy God with all thy heart and with all thy soul and with all thy strength'; and 'Thou shalt love thy neighbour as thyself.' In the old story every listener, from whatever country he came, Parthians and Medes, Cretans and Arabians, heard the message in his own tongue. A great saying speaks to every man in the language which he understands. To the student of science the words mean that he is to put his whole heart into his work, believing that in some way which he cannot fully comprehend it is all worth while, and that every straining to understand his surroundings is right and good ; and, further, that in that way he can learn to be of use to his fellow-men.

THE VOLTA EFFECT.

ADDRESS BY

PROF. ALFRED W. PORTER, D.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

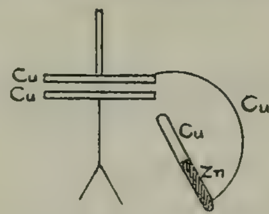
Since the last annual Meeting the Association has lost one who on more than one occasion took part in the discussions of Section A. We had hoped that he would be present also at this meeting. I refer to Hendrik Antoon Lorentz, who passed away on February 4, 1928, in his seventy-fifth year. Lorentz had long been regarded as one upon whom the mantle of Clerk-Maxwell had fallen. For his character as a scientist and as a man I may make reference to the columns of ' Nature ' for February 25, 1928. From the group of appreciations there recorded I select the following quotations : ' For many years Lorentz naturally and by general consent took the leading place in every European conference of physicists.' ' His name recalls especially the Lorentz transformation, the culminating point of one phase of electrodynamical theory and the foundation stone of the next.' ' To British investigators Lorentz was ever a most sympathetic figure. This was due partly to his mastery of our language, partly to his keen admiration of the work of the great English leaders of his time, and above all to the transparent kindliness and charm of his character, with its strict integrity and the engaging candour with which he always admitted and even emphasised such difficulties as he had not been able to surmount.'

We have also to record the regretted death of Dr. Charles Chree on August 12 at the age of sixty-eight. Dr. Chree was superintendent of the Kew Observatory from 1893 to 1925. He was a leading authority upon terrestrial magnetism, atmospheric electricity and related subjects.

The subject that I have chosen for this address is the Volta effect. Volta's discovery was made towards the end of the eighteenth century (1792). One form of experiment is as follows :—

A zinc rod attached to a copper rod is held in the hand. The copper rod is brought into contact with the lower plate of a condensing electroscope, the top plate of which is touched by the other hand. If the connexions are broken and the top plate is raised the gold leaves diverge with negative electricity. This proves that the copper rod was at a negative potential, since the zinc was held in the hand and at the potential of the earth, that is at zero. If the experiment is repeated, but with the copper rod held in the hand and the zinc rod touched to the lower plate, no charge appears, there being a rise from the copper to the zinc accompanied

by an equal fall from the zinc to the lower plate of the electroscope. In this description it is tacitly assumed that the hand brings the metal touched to its own potential, and that that is the earth (or zero) potential.



Volta's own explanation was that there existed in metals an inherent power of separating the two electricities; that is, that each metal possessed what Helmholtz later spoke of as a specific attraction for electricity. But an alternative explanation made the effect depend upon the accidental circumstance that the rods are in air, that there is incipient or potential chemical action, between the air (or moisture in it) and the rods, which creates a drop of potential (of different amounts) between the air and each rod; and that consequently when the twin rods are brought together, their potentials being equalised by a flow of electricity between them, there is still a difference of potential between them and the air. It has further to be supposed that the oxidising properties of the fluids on the hand are not very different from those of the air, and consequently the observed drops of potentials are between the metals and the hands, and not between the metals themselves. The two theories are known as the contact theory and the chemical theory.

The subject from the beginning proved to be a very controversial one. The time was not ripe in Volta's days properly to discuss it. In its more modern form discussion may be said to have begun soon after the acceptance of the two principles of thermodynamics in 1850. The principle of energy and that of entropy put an entirely new complexion upon it.

Early in the nineteenth century a second mode of obtaining a flow of electricity was discovered by Seebeck (1822) which depended on creating differences of temperature in a circuit of two metals. This was the discovery of the thermoelectric circuit. It was inevitable that the two discoveries should become associated with one another, for the thermoelectric electromotive force might be simply due to the temperature variations of the other. The Seebeck effect is very small. A hundred degrees difference of temperature provides an e.m.f. of the order of millivolts at most, while the Volta effect for copper and zinc is of the order of one volt. Whether the two phenomena are intimately related or otherwise it is necessary to discuss them both. It is convenient to give first place in the discussion to the thermoelectric circuit.

Thermoelectric Circuits.

Two wires of different materials are joined so as to form a loop with the two junctions at different temperatures, T_1 and T_2. The elementary facts about such a circuit are, in general:—

(1) A current flows round the loop (Seebeck effect).

(2) Heat is taken in or given out at each junction (the Peltier effect : $=\pi Q$).

(3) Heat is taken in (or given out) at each portion of each wire in amount σ per unit charge per unit rise of temperature (the Thomson effect).

Energy is required to drive the currents ; the electromotive force (E) of the complete circuit is the energy required to pass unit charge across any section arbitrarily cut across either conductor. The principle of energy requires that round the complete loop this shall equal the total heat taken in ; or

$$E=\pi_2-\pi_1+\int_{T_1}^{T_2}\sigma' dT-\int_{T_1}^{T_2}\sigma'' dT.$$

All the coefficients refer to unit charge. It should be noted that if the integration be carried out it will give E as a function of T_2 and T_1.

π_2 and π_1 are the Peltier heat coefficients at the temperatures T_2 and T_1.

σ' is the Thomson heat coefficient in one metal and is sufficiently defined by the equation ; σ'' is the corresponding quantity for the second metal.

There is, of course, nothing in this equation to show how the e.m.f. is localised. It is an equation for a complete circuit and for such a circuit the equation shows that the total e.m.f. depends only upon the temperatures of the two junctions.

Let us now take a second circuit, different only in the fact that the higher temperature T_2 is slightly greater. A similar equation holds good for it, and the difference between the two equations is

$$dE=d\pi_2+(\sigma_2'-\sigma_2'')dT_2$$

$$\text{whence } \frac{dE}{dT_2}=\frac{d\pi_2}{dT_2}+\sigma_2'-\sigma_2''.$$

The suffix 2 indicates that the symbols denote values corresponding to the temperature T_2. This equation is not an equation for one circuit ; it connects the properties of two circuits differing only infinitesimally in the temperature T_2.

At first sight the equation has rather an uncanny (*i.e.* unphysical) appearance because all the symbols, except E, refer to the neighbourhood of the temperature T_2, while E is the e.m.f. round a complete circuit.

One might precipitately come to the conclusion that the events at either of the junctions were influenced by the events at all other points of the circuit.

It is, however, only the rate of change of E due to changing the temperature T_2 with which we are concerned, and it might more logically be written $\left(\frac{\partial E}{\partial T_2}\right)_{T_1}$ because T_1 must be left unchanged.

In the same way, by changing T_1 instead of T_2 we may obtain

$$\frac{\partial E}{\partial T_1}\bigg|_{T_2}=\frac{d\pi_1}{dT_1}+\sigma_1'-\sigma_1''$$

in which everything refers to the lower temperature T_1.

Sir Oliver Lodge has always insisted that E is invariably the e.m.f. round a complete circuit. This is perfectly correct, but we are only concerned with the contribution to its value arising infinitesimally near to either of the extreme temperatures of the circuit, and $\frac{\partial E}{\partial T_2}$ is thus seen to be identical with $\frac{\partial V_2}{\partial T_2}$ where V_2 is the potential-difference at the junction whose temperature is T_2.

We can obtain further information from considerations of entropy. Strictly speaking we are entitled to use the principle of entropy only for reversible cycles, while in several respects the circuits we are using may be irreversible. Several ways are known by which the irreversibility may be diminished to zero in the limit, but no change is thereby made in the conclusions which we come to by ignoring the irreversibility altogether —which we accordingly do.[1]

The entropy change at any part of a cycle is obtained by dividing any heat entry by the absolute temperature at which it enters. The sum of all the changes must be zero for a complete cycle.

The two circuits give

$$\frac{\pi_2}{T_2}-\frac{\pi_1}{T_1}+\int_{T_1}^{T_2}\frac{(\sigma'-\sigma'')}{T}dT=0$$

$$\frac{\pi_2+d\pi_2}{T_2+dT_2}-\frac{\pi_1}{T_1}+\int_{T_1}^{T_2+dT_2}\frac{\sigma'-\sigma''}{T}dT=0$$

$$\text{whence}\quad \frac{\partial}{\partial T_2}\left(\frac{\pi_2}{T_2}\right)+\frac{\sigma_2'-\sigma_2''}{T_2}=0$$

[1] By increasing the lengths of the wires the conduction of heat along each may be indefinitely diminished. By surrounding them with conductors having the same temperature as the wire near to it the loss by radiation, &c., can be diminished. A reverse e.m.f. can be superimposed (by electromagnetic induction or otherwise) so as to reduce the current to zero and thereby diminish the value of the ohmic heat; and so on. Ignoring the irreversibility is equivalent to taking for granted that such precautions have been taken.

By eliminating $\sigma_2'-\sigma_2''$ we obtain

$$\pi_2=T_2\left(\frac{\partial E}{\partial T_2}\right)_{T_1}$$

all of which symbols are related to the temperature T_2 (T_1 being kept constant).

Similarly, by making the change at the lower temperature,

$$\pi_1=T_1\left(\frac{\partial E}{\partial T_1}\right)_{T_2}.$$

Also, by eliminating π_2 (or π_1)

$$\sigma_2'-\sigma_2''=-T_2\left(\frac{\partial^2 E}{\partial T_2{}^2}\right)_{T_1}$$ [2]

All this leads one to realise that $\left(\frac{\partial E}{\partial T_2}\right)_{T_1}$ is identical with $\frac{\partial V_2}{\partial T}$ where V_2 is the local e.m.f. contributed by the junction itself; and that

$$\pi_2=T_2\frac{\partial V_2}{\partial T_2}.$$

Controversialists may be divided between those who believe that the difference of potential (V) at any junction is measured by the heat taken in thereat and those who do not consider that this assertion is justified, but that it must be replaced by the above equation. *It of course does not follow that there is any difference between the two assertions in particular cases*; it remains to be found out whether there is any difference between them or not.

Though this is so, yet of course it may not be assumed *ab initio* that heat entry and external work done are equal to one another. This is the assumption that is actually made by those who write $\pi_2=V_2$, both being expressed in terms of the same units.

It is instructive to enquire what the relation connecting these quantities is for other phenomena.

[2] *Example:*—It is found that in many cases E is given by a parabolic equation which can be written

$$E=a(T_2-T_1)\left[T_0-\frac{T_2+T_1}{2}\right];$$

whence by keeping T_1 constant and differentiating with respect to T_2

$$\pi_2=aT_2(T_0-T_2).$$

Similarly, by differentiating with respect to T_1, the heat removed at T_1 is found to be

$$\pi_1=aT_1(T_0-T_1).$$

$$\text{Also } \sigma_2'-\sigma_2''=aT_2$$

$$\text{and } \sigma_1'-\sigma_1''=aT_1.$$

These are terminal values only and are consistent with taking

$$\sigma'-\sigma''=aT \text{ at any intermediate temperature,}$$

$$\text{or } \sigma'=a'T \text{ and } \sigma''=a''T$$

$$\text{where } a=a'-a''.$$

The general equation which is applicable in any particular group of cases is obtained by applying the principles of energy and entropy to reversible transformations. By taking both these quantities as depending only upon the state of a system the following equations are obtained :—

Group I, Case I.—Perfect gas under uniform pressure.

$$\text{Heat entry} = dH = C_v dT + pdv. \quad \text{Work done} = dW = pdv.$$

In this case, at constant temperature, $dH = dW$.

Case II.—*Any* fluid under uniform pressure,

$$dH = C_v dT + T\frac{\partial p}{\partial T}\Big|_v dv; \quad dW = pdv.$$

Thus, at constant temperature

$$dH - dW = \left(T\frac{\partial p}{\partial T}\Big|_v - p\right)dv.$$

Hence $dH \neq dW$ unless $T\left(\frac{\partial p}{\partial T}\right)_v - p$ remains zero ; that is, unless

$$p = Tf(v)$$

where $f(v)$ means any function of the volume alone.[3]

Take the case of steam formed at a constant temperature of 100° C. Per gram we have

$$\Delta H = 540 \text{ cal/gram}$$

$$pdv \doteq \frac{1650 \times 10^6}{42 \times 10^6} = 40 \text{ roughly.}$$

$$\text{Hence } \Delta H = \frac{540}{40}\Delta W.$$

This is an example in which ΔH is much greater than ΔW.

Group II.—Surface tension, σ.

$$dH = C_A dT - T\frac{\partial \sigma}{\partial T}\Big|_A dA, \; dW = -\sigma dA.$$

$$\text{For water } \frac{1}{\sigma}\frac{d\sigma}{dT} \doteq \frac{1}{500} \text{ at } 300° \text{ Abs.}$$

$$\text{Hence } \frac{dH}{dW} = \frac{300}{500} = \frac{3}{5}.$$

Group III.—Magnetism,

$$dH = C_I dT - T\frac{\partial h}{\partial T}\Big|_I dI. \qquad dW = -hdI.$$

[3] Van der Waal's equation is $\quad p = \frac{RT}{v-b} - \frac{a}{v^2}$

$$T\frac{\partial p}{\partial T}\Big|_v = \frac{RT}{v-b} = p + \frac{a}{v^2}$$

$$\text{Hence } \; dH - dW = \frac{a}{v^2}dv \text{ at const. temp.}$$

Group IV.—Electric condensers,

$$dH = C_q dT - T\frac{\partial V}{\partial T}\Big|_q dq. \qquad dW = -V dq.$$

In neither Group III nor Group IV is $dH = dW$.

These equations are all derived in the same way as for Group I—or alternatively they can be written down at once by analogy. Work can take various forms, but heat and work are always related in the same way thermodynamically.

Surely a contemplation of these cases should act as a deterrent against *assuming* the equality of heat entry and external work done.

Only in a particular case of Group I is the heat entry a measure of the isothermal work. Hence those who claim that in the thermoelectric case π is a measure of V must show that the conditions are analogous to those of a perfect gas, or at least of a fluid whose characteristic equation is $p = T f(v)$.

In all the literature on this subject I find no realisation by the combatants that both sides *might* be asserting the same thing.

Now *does* electricity behave as a perfect gas when it flows through a conductor—through a copper wire, for example?

Attempts have been made to calculate the conductivity of a wire by assuming that the electrons constitute a perfect gas; but, as is well known, all these attempts have broken down. The answer to the question can, however, be found in another way. When Kelvin, in conjunction with Joule, wished to find the difference between real gases and the ideal gas he passed the gas through a porous plug. If the gas became warmer or cooler in passing through (although no heat was admitted) he knew that the gas was not perfect. Experimentally, air became cooler and hydrogen hotter. The difference of behaviour depends entirely upon the value of $T\frac{\partial v}{\partial T} - v$ for the gas. No heating or cooling would be obtained if this expression is zero; or, writing it in an integral form, if $v = Tf(p)$.

Now every time that you pass electrons through a conductor you are conducting a porous plug experiment. The electrons pass through the mesh of atoms like molecules of fluid through a porous solid, and in every case warming takes place (the Joulean heat). It is true that in the electrical case when conducted adiobatically the temperature goes on rising; *i.e.* it is never possible to reach the stationary state for which easy calculation becomes possible. But in principle the same thermodynamics applies to all these phenomena, and the fact that warming occurs is sufficient to prove that the electrons do not flow as a perfect gas.

This being so we are obliged to conclude that the isothermal heat entry at a junction between two metals is not equal to the external work done at the same junction, *i.e.* that the Peltier coefficient is not a measure of the voltage drop at that junction.

The Electron considered as a Solute.

The developments in our knowledge of the electron since 1895 have placed the subject on a new footing. When Sir William Thomson (Kelvin) first gave an explanation of thermoelectric phenomena he spoke of σ as

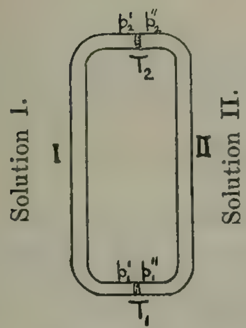
being the specific heat of electricity. There is no clear evidence that he used the term in anything but an analogical way. To Maxwell the idea of the corporeality of electricity was exceedingly distasteful. He assumed that such a phrase as the specific heat of electricity 'was not intended by Thomson, and must not be understood by us, to imply that electricity either positive or negative is a fluid which can be heated or cooled and which has a definite specific heat.' He shelved the question by talking of change of entropy instead. Maxwell's conceptions in regard to the non-corporeality of electricity almost won the day when Hertzian waves were found to be transmitted in free space where no electricity was. But the bodily nature of electricity came to be a real thing in the years succeeding 1895. Negative electricity was isolated as electrons, while positive electricity has not yet been separated from the rest of the atom, and may consist of all of the atom which is not electrons. There is now no difficulty in thinking of electricity as a receptacle of energy which may be communicated to it in the form of heat; that is, it has come fully within the thermodynamical scheme. The question is, which is the best picture that can be given of its position in that scheme?

Now, firstly, when an electric current passes across a junction between two metals, say copper and zinc, it is quite certain that no detectable amount of metal is carried by it across the junction. We are not concerned with the formation of brass (as probably Sir Oliver Lodge has already said). The only things that pass are the electrons which are responsible for conveying the current in each metal. These are tolerably free to move under the influence of an electric force. [They are not set free by the force, for otherwise Ohm's Law would not hold good.] The copper or zinc serves merely as a framework through which their motion occurs. The electrons can get across a boundary between the metals, but the fact that heat-changes occur thereat is evidence that they may need to be helped over—there is a rise (or drop) of potential there, though not of an amount equal to the heat entry. It is convenient to think of this potential, V, as a pressure arising from electrical forces, or more strictly, since V refers to unit charge, a pressure divided by the charge on the electron.

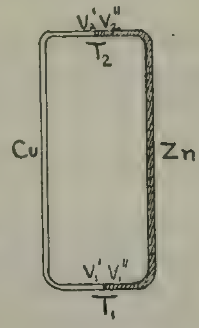
It is clear that thermodynamically we may regard the metal as a solution or binary system, the electrons being the solute. The boundary between the zinc and copper acts as a semi-permeable membrane, since the electrons, and nothing else, can get through it. FitzGerald spoke of the free surface of a solution as the most perfect semi-permeable membrane, but the boundary surface between two metals in regard to electrons runs it very close. There is a difference of pressure (or potential) between the two sides. This is an osmotic pressure. The electrons can also escape to some extent from the sides of the wire; they have a vapour pressure. If the temperature is raised this becomes very conspicuous as thermionic emission. The copper also has a vapour pressure, but much smaller. We have then to deal with a volatile solute dissolved in a practically involatile solvent—at least at moderate temperatures.

This being so, and thermodynamics being superior to the idiosyncrasies of individual mechanisms, we can at once transfer all that we know about the thermodynamics of solutions to the thermoelectric circuit.

OSMOTIC CONSIDERATIONS.



OSMOTIC.



THERMOELECTRIC.

Osmotic pressure at $T_2 = P_2 = p_2'' - p_2'$.

,, ,, $T_1 = P_1 = p_1'' - p_1'$.

Heat of dilution at $T_2 = \left(T_2 \frac{\partial P_2}{\partial T_2}\right)_v$.

,, ,, $T_1 = \left(T_1 \frac{\partial P_1}{\partial T_1}\right)_v$.

Potential difference at $T_2 = V_2 = V_2'' - V_2'$.

,, ,, $T_1 = V_1 = V_1'' - V_1'$.

$\pi_2 =$ Heat entry at $T_2 = T_2 \frac{\partial V_2}{\partial T_2}$ per unit charge.

$\pi_1 =$,, ,, $T_1 = T_1 \frac{\partial V_1}{\partial T_1}$ per unit charge.

Now although the fact that both cases are solutions enables one to write down the general expressions for both, it does not follow that there is precise numerical correspondence. Nevertheless it is instructive to enquire what is found to be true for ordinary solutions.

It is found in practice for solutions such as sugar in water that P can, with fair accuracy, be represented by a simple equation such as

$$P = nRT/(1 - nb).$$

With this equation the

$$\text{Heat of dilution} = T\frac{\partial P}{\partial T} = P.$$

Hence the heat taken in is *nearly* equal to the external work done. Recent measurements of it have been made by Miss D. Hunter and by Perman and Downes, and deviations from this statement have been determined.

On the other hand, in the thermoelectric case

$$\pi = aT(T_0 - T)$$

for many pairs of metals. At temperatures remote from the neutral temperature (T_0) this is of the same form, but in general since

$$\pi = T\frac{\partial V}{\partial T},$$

$$\frac{V}{T} = a(T_0 - T) \text{ or } V - V_{2T_0} = a\left(T_0 T - \frac{T^2}{2}\right).$$

There seems to be nothing in the osmosis of solutions to indicate what the value of the integration constant V_{2T_0} may be.

The second property of solutions is that of vapour pressure or, as it is called, thermionic emission. We have two solutions, Zinc+E and

Copper+E. Each has a vapour pressure for electrons. When equilibrium exists between the metals the vapour pressure must be the same for both.

Now there is a theorem which deals with such cases of equilibrium. This is Margules' theorem. If μ_1 is the molar fraction of the volatile component and p the vapour pressure,

$$\mu_1 \frac{d}{d\mu_1} \log p = \text{a symmetrical function of } \mu_1 \text{ and } 1-\mu_1.$$

This theorem is not quite exact, but at temperatures remote from the critical value the error is one part in a million or less, and may be disregarded. A simple case is that for which the right-hand side can be written $a+2\beta\mu_1(1-\mu_1)$, and when integrated it gives

$$\log \frac{p}{p_0} = a \log \mu_1 + \beta(1-\mu_1)^2.$$

An equation of this kind fits exceedingly well many binary mixtures (even when both components are volatile), the value of β varying in different cases from plus three or four to minus six, and a being often equal to one. The form of the equation indicates that β is the coefficient of mutual action between the components. Its value varies nearly inversely as the absolute temperature, and since the equation may be written

$$p = p_0 \mu_1 e^{\frac{\beta_1(1-\mu_1)^2}{T}}$$

it is seen to have a close connexion with Boltzmann's equation. But the general form of Margules' equation has, I believe, much wider validity than Boltzmann's equation.

Now when copper and zinc with their electrons are in contact-equilibrium with each other they must have the same vapour pressure for electrons—i.e. p is the same for both. Hence

$$\mu_c e^{\frac{\beta_c(1-\mu_c)^2}{T}} = \mu_z e^{\frac{\beta_z(1-\mu_z)^2}{T}}.$$

This is an equation for determining the concentrations (μ) of the free electrons in copper and zinc respectively.

Our present knowledge about the numbers of free electrons in metals requires that μ_c and μ_z be small. Hence approximately

$$\mu_c e^{\frac{\beta_c}{T}} = \mu_z e^{\frac{\beta_z}{T}}$$

$$\text{or } \frac{\beta_z - \beta_c}{T} = \log \frac{\mu_c}{\mu_z}.$$

Now $\beta_z - \beta_c$ is certainly proportional to the work done in the escape of an electron, but we do not know enough about the concentrations (μ) of the free electrons in the metals to make any use of this equation, which is of such importance in connexion with the properties of ordinary solutions. I give it in order to call attention to it as an equation which may some day be of use in elucidating the Volta effect.

More hopeful in giving information is the equation for the latent

heat of the solution in terms of the specific heats. For a substance like water changing phase

$$\frac{\partial}{\partial T}\left(\frac{L}{T}\right)+\frac{\sigma'-\sigma''}{T}=0.$$

For the electrical case we obtained the equation

$$\frac{\partial}{\partial T_2}\left(\frac{\pi_2}{T_2}\right)+\frac{\sigma_2'-\sigma_2''}{T_2}=0.$$

The quantity L I have called the latent heat of dilution. It is connected, however, with the latent heats of evaporation from the two metals at the junction temperature. These latent heats of evaporation are those that come into play in thermionic emission. Prof. O. W. Richardson has measured such latent heats, and concludes that they support the existence of large thermionically excited voltages. Whatever their magnitude it must not be forgotten that π is a measure of the differential latent heat at a junction and π is certainly very small.[4]

[4] I am accustomed to put the matter thus:

Assume that the emitted electrons behave as a perfect gas in the vapour state, having pressure, volume, and temperature connected thus:

$$p=\frac{RT}{v}.$$

Now, any latent heat is given by

$$L=T(v_2-v_1)\frac{dp}{dT}\quad \text{(Clausius)}.$$

The internal latent heat is

$$L_i=(v_2-v_1)\left(T\frac{dp}{dT}-p\right)$$

$$=(v_2-v_1)\,T^2\frac{d}{dT}\left(\frac{p}{T}\right).$$

But v_1 (the volume in the solid) is exceedingly small compared with v; hence very nearly

$$\frac{L_i}{T^2}=R\frac{T}{p}\frac{d}{dT}\left(\frac{p}{T}\right)=R\frac{d}{dT}\log\left(\frac{p}{T}\right);$$

whence, by integration

$$\frac{p}{T}=Ae^{\int\frac{L_i}{RT^2}dT}$$

or putting $p=nRT$ ($n=$ concentration in the vapour state)

$$n=n_0e^{\int\frac{L_i}{RT^2}dT}.$$

If we consider a second metal in equilibrium with the first

$$n'=n_0'e^{\int\frac{L_i'}{RT^2}dT}.$$

But things which are in equilibrium with the same thing are in equilibrium with one another; therefore $n=n'$ and

$$\log\frac{n_0'}{n_0}=\int\frac{L_i-L_i'}{RT^2}dT.$$

L_i-L_i' is the internal latent heat of dilution. This equation is Kirchhoff's equation. Now though the latent heats may be large their difference is usually a small quantity, and it is their difference which is nearly represented by π.

The actual measured value for σ for copper at 150° C. is about 2·5 micro-joules per deg. C. per coulomb. Since the electric charge of an electron is about $1{\cdot}57 \times 10^{-19}$ coulombs, the value of σ for an electron in copper would be $2{\cdot}5 \times 1{\cdot}57 \times 10^{-19} \times 10$ ergs per deg. C., or $3{\cdot}9 \times 10^{-18}$ ergs per deg., while the corresponding quantity for a gas molecule is about 2×10^{-16} ergs per deg. The measured value is considerably less than the usual molecular value. We know, however, that for some metals it is actually negative. This is no doubt due to the fact that, being a negative charge, it gives up energy as it goes up potential at constant temperature, and consequently less heat is needed to raise it one degree at any given temperature. If only the Thomson effect could be reliably measured important information could be obtained of dV/dT in each metal.

Electrolytic Regions.

I must now pass on to consider electrolytic regions, *i.e.* voltaic cells. Volta's own theory was that the driving force was situated at the metal-metal junction. His view was afterwards adopted by Lord Kelvin. This is a specially interesting fact because Kelvin was one of the first to show that the *energy* of the current was supplied by the chemical actions in the cell. This was afterwards slightly corrected by Helmholtz, who showed that strictly E was a measure of the *free* energy per unit charge and not of the total energy.[5]

We can in fact no more ignore the heat taken in in this case than we had a right to ignore the internal work done when dealing with the thermo-electric circuit.

We must be prepared to find that the osmotic conditions in voltaic cells are different from those in metals. Consider the circuit of a Daniell cell: Zn—$ZnSo_4$solⁿ—Membrane—$CuSo_4$solⁿ—Cu—outside circuit—Zn.

The first difference is that it is not merely electrons that move. What happens at the Zinc-Liquid junction? We are not certain. Physical chemists under the influence of Debye are revising their conceptions in regard to solutions. The old dissociation theory assumed that positive and negative ions moved about quite freely unless appropriate collisions occurred, when combination might take place, the amount of combination being calculable from the law of mass action. The theory was exceedingly useful, but there was an outstanding difficulty in regard to 'strong'

[5] For a reversible action

$$dU = dH - dW$$
$$= Td\varphi - Xdx$$
$$\text{or} \quad d(U - T\varphi) = -\varphi dT - Xdx.$$

The quantity $U - T\varphi$ is the free-energy, F, φ = entropy, U = internal energy, X a 'force' doing work in the 'displacement' x.

Hence $-dF = Xdx$ or the work done at constant temperature = decrease of F.

Now F depends only on the state of the system, hence dF is a perfect differential, and we have $\left.\frac{\partial F}{\partial T}\right|_x = -\varphi$, so that

$$F = U + T\left.\frac{\partial F}{\partial T}\right|_x$$

$$\text{or} \quad -U = T^2\frac{\partial}{\partial T}\left(\frac{F}{T}\right).$$

The expression for the internal latent heat on p. 31 is an example of this relation.

electrolytes. These do not follow the law of mass action. Debye assumes complete dissociation, but with electrical attractions between the ions due to their positive and negative charges. These forces give rise to what may be called potential combination following, however, a different law from that of mass action, and the difficulty in regard to 'strong' electrolytes is removed, though only for dilute solutions. The important fact, however, is that some of the zinc goes into the solution, carrying positive charges with it. It goes in not merely by evaporation, as in Nernst's theory, but it is in part pulled in by the SO_4-ions carrying negative charges. Again at the copper plate copper is deposited not freely as a vapour might condense, but is retarded by the attractions of the SO_4-ions in the solution. Both plates act as semi-permeable membranes, passing selected substances and stopping others. So far as we know, no electricity gets through either of these membranes except as a rider on an ion. At any rate this must be so as long as Faraday's laws of electrolysis hold good.

On the other hand the membrane (porous pot, &c.) separating the two solutions acts as a membrane more nearly of the metallic kind. Electrons that were riding on SO_4-ions get through, leaving their mounts behind. Few membranes will act in precisely this way, and considerable variety may therefore exist in the voltage changes at this membrane. It is not unlikely that the voltage there may be of the same order as that at the outside copper-zinc junction, but of opposite sign; for in both cases electrons alone are passing. If this is so, then the electromotive force of a circuit may, at least approximately, be the sum of those arising at the metal-liquid junctions.

From what I have said it will be clear that my opinion is that it is still necessary to be cautious and to avoid dogmatism on this question. Much more detailed experimental knowledge is required before the electric circuit is really understood. The electronic theory in metals still has its difficulties, which it is useless to ignore. It is only by recognising the difficulties that advance is made. On the other hand the experimental difficulties in connexion with the direct measurement of Volta effect are also very great, as all who have made experiments on it must know.

I had hoped to be able to present to you some new experimental data. I am not satisfied, however, that I understand the meaning of the vagaries that often occur, and I do not mean to publish anything now.

I wish to say, however, that I am impressed by the excellent and novel work that is being done by Millikan and by O. W. Richardson on this question.

Both the experiments and the theory are associated with great difficulties. My own opinion is that, though the voltage at the metal-metal junction is likely to be much larger than the chemical school demanded, there is nothing to justify one in going to the opposite extreme and expecting that the *whole* of the electromotive of a circuit is located at that junction. Opposing schools may both take comfort in the thought that in some respects they are both right.

Of course no difficulty is introduced if it is concluded that the contribution of an element of the circuit to the total e.m.f. is not measured by the heat taken in locally thereat. On both sides of the controversy it is well

realised that energy may be introduced at one point of a mechanism and utilised at another. Transmission of energy along rods and belts and across wheels is familiar to everybody; and though some of the modes of transmission may appear curious (*e.g.* through a belt it is transmitted in the opposite direction to that in which the tight part of the belt is moving) yet the *modus operandi* presents no difficulty when it is thoroughly analysed.

The object of this address has been to try to clear up some of the causes of dissension. If I have succeeded in making clear any matters about which any of you had experienced difficulties, I shall be well rewarded.

PHOSPHORESCENCE, FLUORESCENCE AND CHEMICAL REACTION.

ADDRESS BY

PROF. E. C. C. BALY, C.B.E., M.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

The phenomena associated with chemical reaction, and in particular the mechanism of chemical change, form a subject of peculiar interest. The story of the development of ideas from the birth of modern chemistry to the present day is one which to my mind forms the most attractive chapter in the history of our science. It may be that to some of those who earn undying fame by the determination of the constitution of most wondrously complex molecules, to some of those who go down to posterity as masters of synthesis and wizards of organic method, it may be that to these this chapter presents an interest that is languid. On the other hand there are many to whom it makes a great appeal because the subject matter is the fundamental basis of chemical knowledge. I confess my own allegiance with the latter, but it is in a very humble spirit that I venture to speak upon this subject. I do so not with any confident assurance of being able to put forward a theory of chemical reaction which will embrace all the known facts and embody all the views that have from time to time been enunciated, but rather in the hopes of collecting together a number of observations which have been made in fields allied to chemistry and appear to be worthy of consideration by those who seek to find an explanation of the mechanism of chemical reaction.

The allied fields to which I refer are those of phosphorescence, fluorescence and absorption spectra, fields which have been enriched by observations of high accuracy. These observations are of special significance in that they are concerned with the physical properties of molecules in contradistinction to those of atoms. The phenomena of chemical reaction are essentially associated with the absorption and radiation of energy, and it thus seems somewhat strange that little attempt has hitherto been made in considering the mechanism of reaction to invoke aid from the many investigations in these allied fields which obviously deal with the energy changes undergone by molecules. It will be my endeavour to show that the evidence that has been obtained from the study of luminescence and absorption spectra has a very direct bearing on the phenomena of chemical reaction, and that the hypothesis of activated molecules which forms the basis of the modern theories of the latter can be rigidly tested and examined by the former.

One of the most important theories brought forward during recent years is that known as the radiation hypothesis, which was developed

independently by Perrin and by W. C. McC. Lewis. Briefly stated in an elementary way, this theory postulated that molecules in general have no chemical reactivity, and that they become reactive after they have absorbed energy. In order that a specific reactivity be induced, a definite quantity of energy must be supplied to bring each molecule from its initial stage to its reactive state, this quantity being called the critical increment of energy characteristic of the specific reaction.

The fundamental basis of the radiation hypothesis was the extension of the Einstein photochemical equivalent law to include thermal radiation as well. The Einstein law states that in a photochemical reaction the absorption of the radiation takes place in the form of quanta, and that each molecule requires for its activation one single quantum $h\nu_0$, where ν_0 is the characteristic absorption frequency of the molecule in the visible or ultra-violet region of the spectrum. The conception that a single quantum of energy must be absorbed before a molecule can become activated was not only extended but also intrinsically modified in the radiation hypothesis. W. C. McC. Lewis developed from the Planck radiation formula the expression

$$d \log k/dT = Nh\nu/RT^2 \quad . \quad . \quad . \quad . \quad (1)$$

where k is the velocity constant of the reaction and N is the Avogadro constant. By treating the problem from the point of view of statistical mechanics, J. Rice, following the example of Marcelin, obtained an expression which, with a small simplification, may be written

$$d \log K/dT = E/RT^2 \quad . \quad . \quad . \quad . \quad (2)$$

where E is the amount of energy necessary to bring one gram molecule of a gas into its reactive state. If the like terms in these expressions be equated we have

$$E/N = h\nu,$$

that is to say the amount of energy that has to be supplied to a single molecule to cause it to react is one single quantum of absorbable radiation. Although Lewis says that this is simply a statement of the Einstein law which is now applied to thermal or infra-red radiation, it is much more than that. The Einstein law merely states that in a photochemical reaction a molecule absorbs one quantum of radiant energy, $h\nu_0$, and then becomes activated, no assumption being made as to the difference in energy content of the initial and reactive states. The radiation hypothesis states that the difference in energy content of the initial and reactive states, or the critical increment of activation, is a single quantum which can be absorbed from infra-red radiation. The critical increment of energy characteristic of a reaction is neither expressed nor implied in the Einstein law.

It is a simple matter to calculate the critical increment of a reaction from the observed change of the velocity constant with temperature, and by dividing this quantity, expressed in ergs, by the product Nh, to obtain the critical frequency ν. Not only must this frequency be one characteristic of the reactant molecules, that is to say one that can be observed by absorption spectra measurements, but the radiation hypothesis also

demands that exposure of the inactive molecules to radiant energy of that frequency should cause the reaction to take place. As a matter of experimental fact, molecules in their inactive states do not show any evidence of being characterised by frequencies equal to those calculated from the critical increments. This in itself is sufficiently significant to arrest attention, but when it was proved first by Lindemann and then in most elegant fashion by G. N. Lewis that molecules do not react when exposed to radiant energy, not only of the calculated frequency but of a very large range of infra-red frequencies, it was felt on all sides that the radiation hypothesis had been effectively and completely disproved.

The situation thus reached is one of considerable interest. There exist on the one hand large and increasing numbers of photochemical reactions which are obviously stimulated by the absorption of radiant energy. If the Planck theory stand fast, the reactant molecules must be activated by the absorption of the energy quanta $h\nu_0$, since it is well known that the frequency ν_0 is characteristic of them. On the other hand the radiation hypothesis is based on premises which appear to be theoretically sound; nevertheless it has been proved to be untenable. As a result the general consensus of opinion has swung over to activation by collision in thermal reactions. It must, however, be confessed that the present position is very far from being a satisfactory one. In the case of true photochemical reactions it is not possible to believe that activation of the reactant molecules is not produced by the direct absorption of radiant energy. In the case of thermal reactions the evidence disproves the activation by the direct absorption of radiant energy, and activation by collision has been substituted. There are, therefore, two accepted methods of activation, but the fact remains that these two have as yet not been properly married together, the general hope apparently being that any offspring will be legitimised when the union has been scientifically canonised.

When the obsequies of the radiation hypothesis had been sung, it was felt that the corpse had received decent burial. In sympathy with its parents in their bereavement, I venture to point out that this hypothesis may be divided into two parts. The first part is concerned with the critical increment of energy of a reaction, that is to say the minimum quantity of energy, or rather the exact quantity of energy, which is required to bring a molecule from its initial state to its reactive state. Unless the whole conception of different molecular states be dropped, this conception of a critical increment stands on a sure and firm basis. The second part of the hypothesis, namely, that the critical increment can be absorbed as a single quantum of energy by a reactant molecule, is a pure assumption and one that would only be justified by a knowledge that the properties of molecules are in this respect identical with those of elementary atoms. The uncertainty which attaches itself to this assumption impresses me so strongly that I propose to exhume the body in order that the cause of death may be more fully investigated. There exists a considerable amount of evidence which was not before the court and this evidence is worthy of the most serious consideration.

So far as the phenomena of chemical reaction can help us, our knowledge of the physical properties of molecules, and in particular their

change from one to other state of energy content, is singularly meagre, and it would seem that little more can be gained in this direction even by the most intensive study of purely chemical processes. I venture to stress this point of view because I believe that the necessary evidence can only be gained from sources of information which are independent of the processes we wish to explain. Such independent sources of information may be found in the phenomena of phosphorescence, fluorescence and absorption spectra of compounds. Observations in these three fields are sufficiently differentiated from those of chemical reaction to be trusted to give evidence which is free from any bias. I myself believe that these observations when interpreted on the energy quantum theory constitute a mine of information which can render signal service in the quest for a comprehensive theory of chemical reaction.

The term phosphorescence is a broad one and includes both photoluminescence and cathodoluminescence, together with certain subsidiary phenomena. The only one of these that can serve our present purpose is photoluminescence, since a knowledge is essential of the frequency of the activating radiation as well as that of the emitted radiation. It is not possible to give here any detailed account of the many observations, both qualitative and quantitative, of the phenomenon of photoluminescence, but particular attention may be directed to one or two of these which have a special significance in the present connection.

It would perhaps be advisable first to describe very briefly the principal facts which have been established. In the first place the molecules of the phosphore are brought into a state of higher energy content, or the activated state, by the absorption of radiant energy. The phosphorescent emission is the radiation of energy during the change of the molecules from the activated state to the original state, and this energy is equal in amount to that gained during the activation. The persistence of the phosphorescence, that is to say the period of the time during which the luminescence persists, is a measure of the stability of the activated state. The more stable is the activated state, the longer is the persistence, and *vice versa*. The intensity of the luminescence is in inverse ratio to the persistence. After a definite quantity of energy has been absorbed by the phosphore, then in the radiation of that quantity in the form of phosphorescence the velocity must affect the persistence and intensity in opposite senses. Since the phosphorescent emission is the integration of the individual radiation of a number of molecules, the intensity decreases with time as the number of molecules in the activated state becomes smaller. If the intensity at any time t be measured in relation to the initial intensity ($t=0$) then

$$I^{-\frac{1}{n}}=a+bt$$

and in the majority of cases $n=2$.

The stability of the activated state is determined both by the temperature and by the concentration of the phosphorogen in solid solution in the diluent. The higher is the temperature, the less stable is the activated state, and there always exists an upper temperature limit, characteristic of every phosphore, above which no phosphorescence can be observed. The stability of the activated state is the greatest with a pure substance,

and in order to observe phosphorescence at temperatures below the upper limit, it is necessary that the phosphorogen be in dilute solid solution in some diluent. This was first observed by Lenard and Klatt with their alkaline earth sulphide phosphores, and more strongly emphasised by Urbain and Bruninghaus in the case of the rare earths.

The foregoing is a brief account of the characteristics of photo-luminescence, and we may now consider in detail one or two of these, selecting as the first the relation between the frequencies of the exciting radiation and the emitted radiation. In the alkaline earth sulphide phosphores the phosphorescent radiation is very often complex in the sense that it consists of several separate emission bands. Lenard and Klatt, however, satisfied themselves that each emission band is characteristic of a single activated state, since each has its own frequency of activation and its own upper temperature limit. The relation between the absorption band at which activation takes place and the emission band after activation is an intimate one, and it has been shown by later work on less complex phosphores that the absorption and emission bands have structures which are analogous.

Now Lenard and Klatt established the very important fact that phosphorescent emission is not a truly reversible process. It is not in any way possible to activate a phosphore by exposing it to radiation of the same frequency as that which it emits when it has been activated. It is only possible to activate a phosphore by means of radiant energy of the same frequency as that of its characteristic absorption band which lies on the short wave-length side of the characteristic emission band. In short, these investigators proved the complete validity of Stokes' law, and as the result of later work on true phosphorescence this law has been proved invariably to hold.

The importance of this may at once be recognised if the facts be stated in more scientific phraseology. When an activated phosphore is emitting its characteristic luminescence each activated molecule radiates a single quantum of energy in passing from the higher energy state to the lower energy state, the total luminescence being the sum of all these radiated quanta. In the process of activation the change from the lower to the higher state is caused by the absorption of that same quantity of energy by each molecule, and in view of the radiation as a single quantum it is legitimate to assume that it is absorbed as a single quantum, nothing being expressed or implied as to the mechanism of the absorption. Each molecule, therefore, requires for its activation a critical quantum of energy $h\nu_1$, and the value of ν_1 may be directly obtained from the measurement of the luminescence. The proof given by Lenard and Klatt and by others that Stokes' law is valid indicates that it is impossible to activate a phosphore by means of radiant energy of the frequency ν_1, and that the critical quantum of activation cannot be supplied to a molecule by a singular absorption process. There exists, therefore, in this respect a sharp differentiation between the physical properties of molecules and atoms.

The lethal dose of criticism which killed the radiation hypothesis was based on the experimental proof that molecules are not able to do this very same thing, namely, absorb their critical quanta of activation $h\nu_1$

at the calculated frequency ν_1. The radiation hypothesis was killed because the assumption of the second part was made in ignorance of what molecules can do and cannot do.

It may be argued that the activated molecular states which are responsible for phosphorescence must be essentially different from those which function in chemical reaction, because their life periods are enormous compared with those of chemical processes. The fact, however, remains that in a series of different energy levels the uplift from a lower to a higher level cannot be achieved by the absorption of radiant energy of the frequency corresponding to the energy difference. The stability of the activated states in the field of phosphorescence and its remarkable variation with temperature are matters of great importance, but too much stress need not be laid upon them at this stage of the argument. A possible explanation will be given later.

It may be pointed out that there is a close similarity between the effective methods of activation in the fields of photoluminescence and photochemistry. In each the activation is achieved by exposing the inactive molecules to radiant energy of a frequency equal to that of a characteristic absorption band of the inactive state, and this frequency is invariably greater than that calculated from the quantum of activation. Stokes' law, therefore, may be said to apply to photochemistry as well as to photoluminescence.

In view of the mechanism of activation which is common to photoluminescence and photochemistry, it is legitimate to inquire into the destination of the excess of the energy absorbed over the critical quantum of activation. The energy quantum absorbed by a single molecule may be denoted by $h\nu_0$ and the critical quantum of activation by $h\nu_1$, where ν_0 is greater than ν_1, and the question is what happens to the energy difference expressed by $h\nu_0 - h\nu_1$. In the case of photoluminescence there is no doubt of the value of $h\nu_1$, since this may be calculated from the observed emission band, and $h\nu_0$ is also known from measurements of the absorption band or activating frequency. The course of events during activation may be represented by the diagram shown in fig. 1, where energy content is expressed on the ordinates and time on the abscissæ.

The initial level of a molecule is represented by A and the energy level of the activated state by the horizontal line C. The difference between the two levels is $h\nu_1$, and this quantum is radiated when the activated molecule returns to its initial state A. When the molecule in its initial state absorbs the quantum $h\nu_0$ it is raised to the level B, which is higher than the level C. Since the phosphorescent emission is that of the quantum $h\nu_1$, the molecule after being initially raised to the level A must immediately fall to the C level with the radiation of the energy $h\nu_0 - h\nu_1$. If the initial level A is a definite energy state of the molecule, it is legitimate to assume that the energy difference is radiated as a single quantum $h\nu_2$. It may be suggested that this radiation during activation by light of frequency greater than that corresponding to the critical quantum of activation is the origin of fluorescence. Apart from any other argument it is necessary that the radiation of some energy must accompany the activation of a molecule by light if Stokes' law is generally valid, and the view now brought forward is that under certain conditions this energy

can be radiated as a single quantum of fluorescence. The really essential condition for this to take place is that the molecule can exist for a finite period of time at the energy level C.

In all cases of photoluminescence the criterion exists for the radiation of excess energy as a quantum of fluorescence, since the phosphorescent emission gives direct evidence for the existence of the molecule in the energy level C in fig. 1. Fluorescence, therefore, should always be exhibited during the photo-activation of a phosphore. Lenard and Klatt in their investigations of photoluminescence recorded the fact that in general the intensity of the luminescence showed a sudden and marked diminution at the instant the exciting radiation was removed. It will

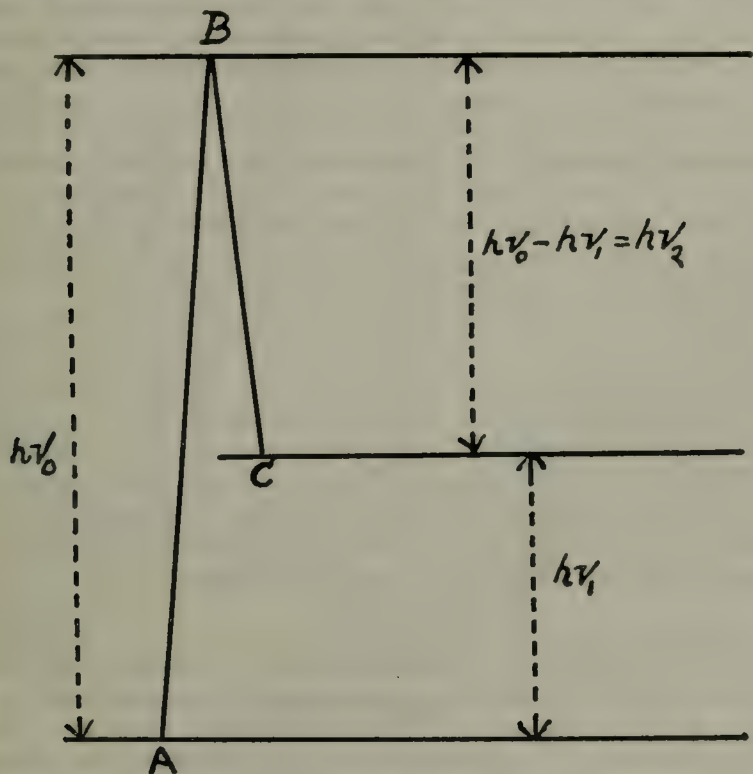


FIG. 1.

be remembered that they defined two 'instantaneous' states, characteristic of each emission band, when the luminescence vanished completely at the instant the activation was stopped. These two states are determined by the temperature, and there lies between them an intermediate state when true phosphorescent emission with measurable persistence is observed. There is no doubt that in the lower instantaneous state the stability of the activated molecules is so great that the phosphorescent emission is too small to be observed. There is also no doubt that in the upper instantaneous state, which has a very small temperature range immediately below the upper temperature limit, the stability of the activated state is so small that the whole of the phosphorescent emission takes place within a fraction of second after activation has ceased. In the intermediate

region the stability is such that the luminescence can be observed and measured without difficulty.

The sudden and complete disappearance of luminescence in the lower instantaneous state when the excitation is stopped must be entirely due to fluorescence, since no phosphorescence is visible. The energy of activation remains stored up and can only be released by raising the temperature. In the intermediate state phosphorescence is always visible to a greater or less extent and in consequence the presence of fluorescence will be recognised by a sudden fall in intensity at the instant when the exciting radiation is cut off. Both these phenomena have been established by Lenard and Klatt's work.

It must be remembered that the one essential criterion for fluorescence is the existence with a finite stability of an energy level intermediate between the initial level and the super-activated level to which the molecule is raised by absorbing the quantum $h\nu_0$. It is by no means necessary that the stability of the intermediate level be sufficiently great for delayed or phosphorescent emission to be visible when the molecule changes from this level to its normal level. The conditions for phosphorescence are far more restricted and rigid, one of these being that the phosphore must be in the solid state. It is, therefore, not surprising that fluorescence is of far more frequent occurrence than phosphorescence.

Attention has already been directed to the close similarity between the activation processes in photoluminescence and in photochemistry. The principle of fluorescence radiation must also apply to photochemical reactions, in all of which the activating quantum is greater than the actual energy of activation. The course of events must again be that shown in fig. 1, with the simple difference that in photochemistry the existence of the molecule in the energy level C will be established by the occurrence of a chemical reaction, the critical increment of which is $h\nu_1$. Here again, therefore, the relation should hold that

$$h\nu_0 = h\nu_1 + h\nu_2,$$

where $h\nu_0$ is the quantum of energy absorbed at the characteristic molecular frequency in the ultra-violet, $h\nu_1$ is the critical increment and ν_2 is the frequency of the fluorescence. It would seem, therefore, that the suggested explanation of fluorescence may be put to a very severe test by the quantitative study of photochemical reactions. Some preliminary observations have been carried out at Liverpool by Mr. Leathwood and these give definite support. The examples selected were not chosen from known photochemical reactions; rather was it considered desirable to determine whether photochemical reactions take place under conditions when fluorescence is visible and do not take place when fluorescence is not visible. Gas reactions have not been investigated owing to the difficulty of observation of the fluorescence of gaseous systems.

Some years ago F. O. Rice investigated the sulphonation of certain phenolic ethers and at the same time he observed the absorption spectra of these substances. A typical instance of the phenomena observed is given in fig. 2, which shows the absorption spectra of anisole. The absorption band A is that exhibited by the ether in alcoholic solution, whilst the absorption band B is that exhibited by the ether in solution

in concentrated sulphuric acid. The shift in the absorption band towards the longer wave-lengths on change of solvent is very marked. The addition of a little (4 eq.) strong sulphuric acid to the alcoholic solution makes no measurable difference in the absorption curve, and no sulphonation takes place in that solution. On the other hand the ether undergoes sulphonation in the concentrated sulphuric acid solution, the reaction velocity being very slow indeed at 15° and rapid at 50°.

Now the alcoholic solution of anisole is strongly fluorescent, the emission band having the same frequencies as the absorption band B in fig. 2, that is to say, the frequency of the fluorescence of the alcoholic solution is the same as the frequency of the characteristic absorption band of the sulphuric acid solution. The suggestion may at once be made that the final activated state produced when the ether in alcoholic solution absorbs its characteristic quantum $h\nu_0$, is that activated state which enters into

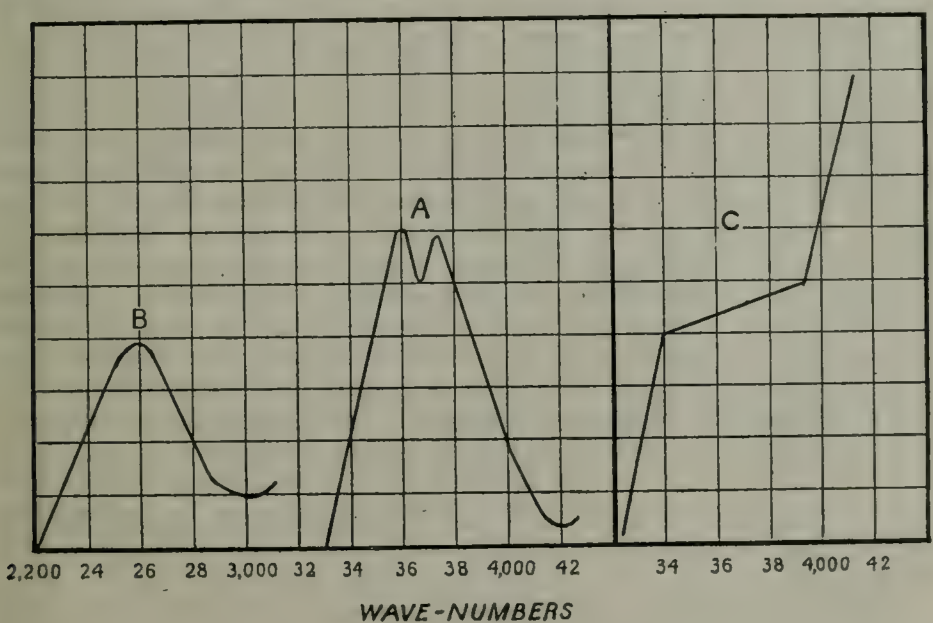


Fig. 2.

the sulphonic acid reaction. In other words, the irradiation of the alcoholic solution, to which a little sulphuric acid has been added, by light of the frequencies of the absorption band A should induce the formation of the sulphonic acid. This was proved to be the case. The acidified alcoholic solution of anisole was irradiated with the light from a quartz mercury lamp for 96 hours, after which the solution was diluted with water and neutralised with barium hydroxide. After filtration from the insoluble barium sulphate, the solution was extracted with ether in order to remove any unchanged anisole. None, however, was recovered. On evaporation the barium salt of the sulphonic acid was obtained in approximately quantitative yield and there was no evidence of the formation of ethyl-sulphuric acid.

In fig. 2 the curve C represents the absorption curve of the sulphuric acid solution of anisole after it has been allowed to remain at 50° for a

few hours and is the absorption curve of the sulphonic acid. It was found that the sulphonic acid prepared photochemically gave an absorption spectrum almost identical with that represented by curve C.

Exactly similar experiments were carried out with para- and ortho-nitroanisole, the absorption curves of which in alcoholic and sulphuric acid solution are very analogous to those shown in fig. 2. Both of these ethers in strong sulphuric acid solution on remaining at 50° react to give their sulphonic acids. These nitro compounds, however, differ from the parent anisole in the fact that in alcoholic solution they exhibit no trace of fluorescence. This suggests that the super-activated states produced when they absorb light at their characteristic absorption bands do not pass into the activated state required for the sulphonation reaction.

Acidified solutions of each nitro compound were irradiated by the light from the quartz mercury lamp for 96 hours and the solutions were treated in exactly the same way as described above in the case of anisole. The results were, however, entirely different. The nitro compounds were recovered from the ether extract, no barium salt of a sulphonic acid was found, and barium-ethylsulphate was obtained in considerable quantities.

Although no more can be claimed for these observations than that they are preliminary, yet the evidence they afford is in striking agreement with that obtained from the photoluminescence phenomena. In the photochemical reaction the radiation of the fluorescence quantum $h\nu_2$ during activation gives an independent proof of the formation of the activated state, and also indicates that the critical increment of activation of a molecule is numerically equal to $h\nu_0 - h\nu_2$. In the case of photo-luminescence the radiation of the critical increment of activation as a single quantum of phosphorescence per molecule indicates that this critical increment of activation is in fact a single quantum per molecule. It would thus seem that independent evidence has been obtained in favour of the first part of the radiation hypothesis, although it has now been shown that the supply of the activating quantum to the reactant molecule cannot under any circumstances be achieved by a simple process of absorption.

The theory of fluorescence now advanced may be considered as being a reasonable one, but it is advisable, before the main argument is pursued further, to examine it in more detail. In the first place the question may be asked as to the course of events when phosphorescence is absent and no chemical reaction takes place. All that the theory states is that any molecule on exposure to radiant energy of its characteristic frequency ν_0 in the visible or ultra-violet region absorbs a single quantum $h\nu_0$ and is raised to a high energy level which has a very short life period. This super-activated state tends to return to its initial state with the radiation of energy numerically equal to $h\nu_0$. Under conditions not yet defined there can exist an intermediate level with a finite stability, and then the molecule falls from the high level to this intermediate level, and in so doing radiates the energy difference between these two levels as a single quantum of fluorescence. The intermediate level may be sufficiently stabilised by the conditions to exhibit the phenomenon of phosphorescence when the final fall to the initial level takes place, or, alternatively, the intermediate level may have a very short life period and may be recognised

by virtue of its chemical reactivity. If this intermediate level does not exist, then neither fluorescence nor phosphorescence will be exhibited, and since optical resonance is unknown with compound molecules, the energy numerically equal to $h\nu_0$ is radiated in the infra-red. If the intermediate level exists, then fluorescence will be exhibited as the molecules fall to that level from the high level first produced. If the molecule when in the intermediate level undergoes no chemical reaction, the critical increment of activation of the intermediate level will also be radiated when the molecule finally reaches the initial level. It may be noted that in all cases of gases and liquids, where phosphorescence never occurs, the difference between the frequencies of the activating and fluorescence radiations is small. The critical quantum of activation, which is the difference between the absorbed and fluorescence quanta corresponds to a frequency in the infra-red.

As already stated, the theory involves the view that the activated states responsible for phosphorescence are similar to those which enter into chemical reaction, and it might be argued that they must be of markedly different type, since the life-periods of the former may be very long, whilst those of the latter are known to be very short. Such an argument, however, is based on the assumption that it is not possible to vary the life-periods of these intermediate states of activation by change of conditions. There is no justification for this assumption ; and indeed the evidence is against it, since remarkable variations in the life-period can be produced by change of temperature alone. For example, Lenard and Klatt showed that by raising the temperature the life-period of the activated state in a phosphore could be reduced from days or hours down to an exceedingly small fraction of a second. Then again von Kowalski showed that many substances in alcoholic solution, which only exhibit fluorescence at room temperatures, develop marked phosphorescence when cooled in liquid air.

Attention may be directed once again to the absorption spectra observations which were recorded in fig. 2 on page 43, and in particular it may be noted that the critical increment of the sulphonation reaction $h\nu_1$, is given by the product of the Planck constant into the difference between the central frequencies of the absorption bands shown by the anisole in solution in alcohol and in strong sulphuric acid. This follows at once from the fact that the fluorescence quantum of the anisole in alcoholic solution is equal to the quantum absorbed by the anisole in sulphuric acid solution. The conclusion would seem to be obvious that the absorption band of the anisole in sulphuric acid solution is that characteristic of the activated state which in some way has been stabilised by the sulphuric acid. The stabilisation is proved by the fact that no measurable sulphonation takes place when the solution is allowed to remain at ordinary temperatures. At 50°, however, the sulphonation takes place with measurable velocity.

Two points of interest may be mentioned which arise from this. In the first place it would seem that the raising of a molecule from a lower to a higher energy level is accompanied by a shift in the characteristic absorption band in the visible or ultra-violet region towards the longer wave-lengths. This also occurs when phosphores are activated, for the

absorption bands of the inactive materials lie in the ultra-violet, and those of the activated substances lie in the visible region.

In the second place it follows that the same super-activated state is produced when the inactive molecule absorbs the quantum $h\nu_0$ at its characteristic frequency, and when the chemically reactive molecule absorbs the quantum $h\nu_2$ at its characteristic frequency. In this way a possible connection with the radiation hypothesis is indicated. W. C. McC. Lewis developed a relation whereby the observed heat of a reaction may be calculated from the critical increments of activation. As stated on page 36 he obtained the expression

$$d \log k/RT = Nh\nu_x/RT^2$$

where hv_x is the critical increment of activation and k is the velocity constant. If the reaction be monomolecular and reversible then

$$d \log k^1/RT = Nh\nu_y/RT^2$$

where $h\nu_y$ is the critical increment of the resultant of the forward reaction and k^1 is the velocity constant of the reverse reaction. It follows that

$$d \log K/dT = Nh(\nu_x - \nu_y)/RT^2$$

where K is the equilibrium constant. Comparing the last expression with the van't Hoff isochore

$$d \log K/dT = -Q_v/RT^2,$$

Lewis concluded that the heat absorbed per stoichiometric quantity of the reactant transformed is given by

$$-Q_v = Nh(\nu_x - \nu_y),$$

that is to say, the heat involved in the reaction is equal to the critical increment of the resultant *minus* the critical increment of the reactant.

In this argument there is involved the view that in a reversible monomolecular reaction the activated reactant and activated resultant molecules are indistinguishable from one another. Applying this to a monomolecular photochemical reaction which is reversible it follows from what has gone before that the photochemical quanta may be substituted for the critical increments in Lewis' expression. The observed heat of the reaction will be given by

$$Q_v = Nh(\nu_r - \nu_0)$$

where ν_r and ν_0 are the characteristic ultra-violet frequencies of the resultant and reactant molecules, respectively. A near approximation to a monomolecular photochemical reaction is afforded by the conversion of oxygen into ozone, which is reversible. The central wave-lengths of the characteristic ultra-violet absorption bands of these two substances are very near to 185 $\mu\mu$ and 250 $\mu\mu$, respectively, the corresponding frequencies being $\nu_0 = 1{\cdot}622 \times 10^{15}$ and $\nu_r = 1{\cdot}2 \times 10^{15}$. The observed heat of reaction will be

$$-Nh \times 4{\cdot}22 \times 10^{14} \text{ ergs or } -36{,}400 \text{ calories.}$$

This is very near to the accepted heat of formation of ozone.

It may be concluded from the foregoing that a definite position has been reached which is of some interest. The radiation hypothesis states that the first stage of a chemical reaction is the activation of each moelcule

of the reactant by the absorption of one quantum of energy, which has been called the critical quantum of activation. Evidence gained from the experimental investigation of the phenomena of photoluminescence gives strong support to the reality of this critical quantum of activation, but entirely disposes of the possibility of a molecule gaining this quantum by a single absorption process. The photochemical activation of molecules has been discussed in the light of the evidence gained from the fields of photoluminescence and absorption spectra and the destination of the whole of the energy gained by a molecule when it absorbs its photochemical quantum has been traced. Lastly, the connection between the observed heat of a reaction and the critical increments of activation, derived by the radiation hypothesis, has been extended to the photochemical quanta, which is an advantage, since the photochemical frequencies can be directly observed by spectroscopic methods. It may even be considered that the exhumation of the radiation hypothesis has been partly justified.

There is no doubt, however, that this partial justification raises the question of thermal reactions in a form which is even more acute than was the case at the inception of the radiation hypothesis. The inability of a molecule to gain its critical quantum of activation by means of a single absorption process has been demonstrated in a far wider field than was covered by the experiments of Lindemann and G. N. Lewis, which as a matter of fact were devised *ad hoc*. Unless some mechanism exists whereby a molecule can gain its critical quantum of activation from a source of infra-red radiation, photochemical activation must be viewed as an abnormal event and the exhumed radiation hypothesis must be re-interred at once and for all time. It is only fair to ask that the question of thermal reaction be approached and discussed entirely without prejudice, and this is all the more necessary because it has generally been felt that not a single hope remained for the hypothesis and men's thoughts have turned to activation by collision with a tendency to exclude any other possibility.

I have been led to re-open this question by some recent observations which appear to throw new light on the problem. These observations encourage me to suggest a possible mechanism of activation by infra-red radiation. Some justification may be found in the fact that it offers an explanation of many of the difficulties that have been met with in interpreting the phenomena observed in absorption spectra.

Mr. Hood at Liverpool has succeeded in determining the temperature coefficient of the reaction whereby carbohydrates are photosynthesised from carbonic acid in the presence of pure nickel carbonate. The experimental method consists in the irradiation of a suspension of the carbonate in pure water, maintained by a stream of carbon dioxide, by the light from an ordinary tungsten filament lamp. The yield of the carbohydrates at various temperatures between 5° and 46° has been determined with considerable accuracy. The investigation only became possible when a satisfactory method had been devised for the preparation of pure nickel carbonate. The method consists in the electrolysis of pure water, saturated with carbon dioxide, with nickel electrodes. The carbonate is collected, dried at 100°, and then heated at 140° for thirty minutes. It is then powdered and passed through a 100-mesh sieve, after which it is

activated by irradiation with white light for 18 hours. The powder must be used very soon after it has been activated.

In fig. 3 is shown the relation between the temperature and the yield, and it may be seen to be linear between 5° and 31°. This result is of some interest in view of the fact that pure photochemical reactions have a temperature coefficient of unity.

In seeking for an explanation of the temperature coefficient it is necessary to review all the known facts. It has previously been shown that

1. Carbonic acid in aqueous solution is not acted on by white light;
2. Carbonic acid when adsorbed on a coloured surface does not react in the dark;
3. Carbonic acid when adsorbed on a coloured surface and irradiated by white light reacts to give carbohydrates.

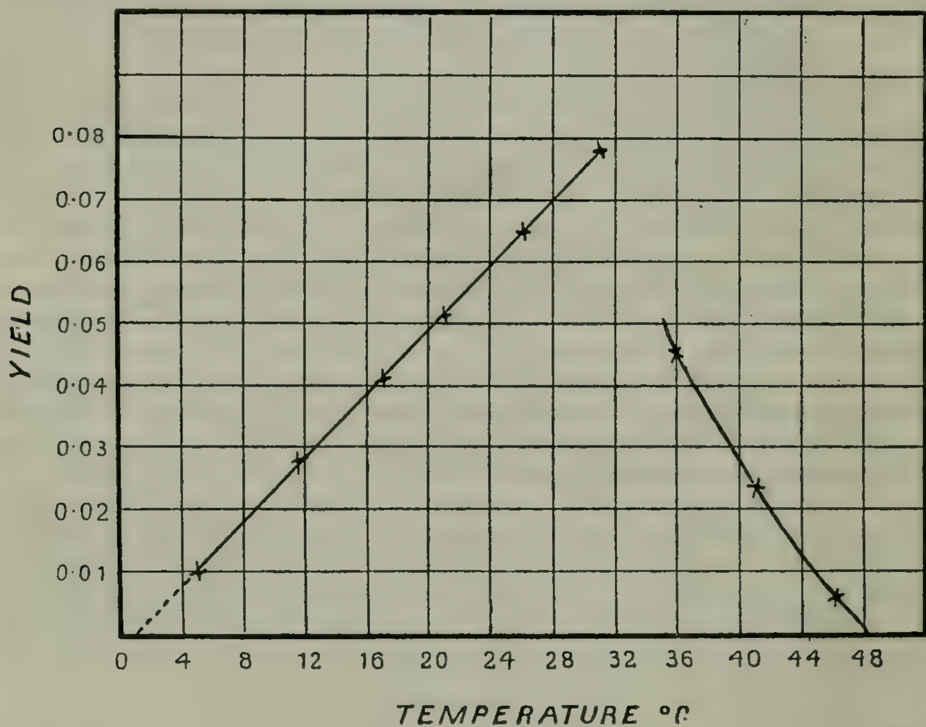


Fig. 3.

It follows as a necessary conclusion from the facts that the complete activation of the carbonic acid must take place in two stages, namely, partial activation by adsorption with the formation of a molecular state capable of absorbing some rays within the visible spectrum, whereby the activation is completed by photochemical means. Furthermore, the number of partially activated molecules which are able to enter into the final reaction is in linear proportion to the temperature. It is this first stage of partial activation which is of interest in our quest, since it is evident that the adsorption process alone is not sufficient to bring the molecules into a state which enables them to react photochemically under the influence of visible light, the supply of heat energy being necessary to add the finishing touch to the partial activation.

There is a striking analogy here with anisole and the other phenolic ethers and their nitro derivatives in solution in concentrated sulphuric acid which were referred to above. There can be no doubt that the ether molecules in the acid solution have gained their critical quanta of activation, and yet their activated states must be stabilised in some way, since no measurable sulphonation takes place at ordinary temperatures. When the solution is warmed at 50° the expected reaction proceeds. This stability of the activated states has placed great difficulty in the way of explaining many observations of absorption spectra.

Now it is very probable that there is one factor which is common to the two sets of observations, namely the existence of a complex, that is to say an adsorption complex of carbonic acid and nickel carbonate in the one and an addition complex or solvate of the ether and sulphuric acid in the other. If the mechanism of complex formation be considered it would appear that two methods are possible whereby a complex can be stabilised. The most usual case is when two components form a complex with a loss of energy, and such a complex will only be resolved into its components by the supply of energy equal to that lost in its formation. As an example of this type of complex the salt of an organic base such as aniline may be instanced, this type having a positive heat of formation.

On the other hand it may be suggested that another possibility exists, namely the formation of an addition complex of two components, one of which yields a definite amount of energy to the other. Such an energy transference, so far as external evidence is concerned, will be an isothermal process. It may further be suggested that the amount of energy given up by the first component to the second component is equal to the critical quantum of activation of the second component. Such complexes will not be formed between any two molecules, but only between two which satisfy the conditions, the criterion being that a molecule of one compound, possibly by loss of rotational energy, can give to the molecule of another compound, energy equal to the critical quantum of activation of that molecule. A complex of this type may be denoted by the symbol $A^{-}B^{+}$, where B has gained its critical quantum of activation at the expense of the rotational energy of A.

Let it be accepted that such complex formation is possible in order that the properties of these entities and their probable influence on the phenomena under discussion may be critically examined. It may first be concluded that, even though the molecule B has become activated, the reaction characteristic of the activated state will not take place until the energy defect of the molecule A has been restored. In other words the activated state of the molecule B has become stabilised. In the second place the resolution of the complex into a normal molecule of A and an activated molecule of B will be secured by making good the defect in the rotational energy of the molecule A. The formation of a free molecule of B in the activated state is no longer a process of direct activation by radiant energy, which has proved to be impossible, but an increase in the rotational energy which, as is known, can be effected by means of infra-red radiation.

This hypothesis may in the first instance be applied to the phenolic

ethers, all the relevant facts of which have already been stated. The quantitative relation between the absorption bands of these substances leaves little or no doubt that each ether in concentrated sulphuric acid solution has in some way gained its critical increment of activation, and in spite of that fact the ether does not undergo sulphonation at ordinary temperatures. It has always been very difficult to understand why this activated state is a stable one and why the reaction characteristic of that state does not take place unless the solution is warmed. The explanation is simple enough on the present hypothesis. The entity present in sulphuric acid solution is a complex or solvate of the ether and sulphuric acid, in which the ether molecules have gained their critical quanta of activation at the expense of the rotational energy of the sulphuric acid molecules. The reaction to give the sulphonic acid and water cannot take place within that complex, since the photochemical experiments prove that the reaction takes place between the activated molecules of the ether and free sulphuric acid molecules. The complex molecule, therefore, will be stable below a certain temperature. On raising the temperature the defect in the rotational energy of the sulphuric acid molecules will be made good and the sulphonation will then take place.

The hypothesis also offers an explanation of the temperature coefficient of the photosynthesis of carbohydrates from carbonic acid, referred to above. In this case the complex is the adsorption complex of carbonic acid and nickel carbonate, in which the carbonic acid molecule has gained, at the expense of the rotational energy of the nickel carbonate molecule, its critical quantum of activation to the intermediate level. So long as the complex exists the carbonic acid will not undergo reaction when it is irradiated by white light, and in consequence no measurable reaction takes place at the lower temperatures, even though the carbonic acid molecule may be raised by the absorption of light to its higher energy level. When the temperature is raised the energy defect of the nickel carbonate is made good and the activated carbonic acid molecules are set free. Two alternatives exist as regards the final activation of the partially activated carbonic acid molecules by their absorbing light. Either the partially activated molecule gains its second increment of activation by absorption of the photochemical quantum when it exists in the complex, in which case the increase in temperature will set free the fully activated molecule, or the second increment of activation is gained by the absorption of the photochemical quantum at the instant the partially activated molecule is set free by the rise in temperature. In either case the fully activated molecules react to give activated formaldehyde and oxygen, this being immediately followed by the polymerisation of the activated formaldehyde to give the hexoses. The evidence is strongly in favour of the first alternative, as will presently be explained.

It must be emphasised that the temperature is a most important factor, and there must be for every complex a characteristic temperature limit, below which it is completely stable. In the case of the phenolic ether complexes with sulphuric acid it happens that this temperature lies above 15°, since the sulphuric acid solutions of the ethers undergo no measurable change when allowed to remain at that temperature for

some weeks or even months. The ether may be quantitatively recovered when the solution is poured on to crushed ice. In the case of the adsorption complex of nickel carbonate and carbonic acid the characteristic temperature limit lies at 1·2°, as shown by the dotted extension of the straight line in fig. 3.

When the temperature is progressively raised above the characteristic limit an increasing number of complexes will be resolved in unit time, and the reaction velocity will increase. It may be said, therefore, that the stability of the complexes progressively decreases as the temperature is raised above the temperature limit, and it follows that there must be an upper temperature limit above which the complex will have no measurable stability, and at this temperature the reaction velocity of a simple chemical reaction will reach a maximum and will indeed be instantaneous, if such a word can be applied to a process involving the mixing together of the reactants. The photosynthesis reaction is differentiated by the fact that it consists of two stages, and the temperature limits concern only the stability of the adsorption complex characteristic of the first stage.

The hypothesis of complex formation also offers an explanation of the phenomena of photoluminescence. There is one outstanding fact in connection with the activation of the phosphorogen in a phosphore which indicates the presence of a complex of the type we are dealing with. In all cases where the activating wave-lengths have been measured, these are longer than those which are characteristic of the phosphorogen in the free state. This at once leads to the view that each phosphorogen molecule has formed a complex with a molecule of the diluent, and within that complex the phosphorogen exists at a level of higher energy content than the normal. The stability of the complex will be determined by the temperature as it can only be resolved into its components by the supply of infra-red radiation to make good the defect in the rotational energy of the diluent molecule. Even though the phosphorogen component is raised to a still higher level by absorption of its characteristic quantum at the ultra-violet frequency, the complex will remain in its stable state provided that the temperature is below the lower limit characteristic of the complex. An instance of an exactly analogous phenomenon is the very striking fluorescence of benzaldehyde in concentrated sulphuric acid solution. In this case the aldehyde within the complex absorbs and radiates energy without its stability being affected. It may therefore be suggested that even after the phosphorogen has been raised to a higher level of activation than that which it reaches in the actual formation of the complex, the new state is no less stable than the complex itself. If that be so the whole of the phenomena of photoluminescence which have been previously described will find a simple explanation. There will be a lower temperature limit below which the activated complex will be completely stable, that is to say no phosphorescence will be observed. When the temperature is raised above the lower limit the region of partial stability will be entered and phosphorescent emission will begin, and progressive rise of temperature will progressively increase the number of complexes that are resolved and the intensity of the phosphorescence will increase. Since there are present a finite number of complexes the

total persistence of the emission will decrease. At any constant temperature between the lower and upper limits the intensity will have a definite rate of decay. Just below the upper temperature limit where the stability is vanishingly small the persistence will be vanishingly small and the intensity will be the maximum. Up to this stage the phenomena will be identical with those of a chemical reaction, the criterion of intensity of phosphorescence being substituted for the criterion of reaction velocity. When the upper temperature limit is passed the complex will no longer have any stability and will no longer exist. No phosphorescence or fluorescence will be possible, since these depend on the stable existence of the complex with its power of retaining the energy which it absorbs at its characteristic frequency in the ultra-violet. These phenomena are identical with those observed by Lenard and Klatt.

One further piece of evidence, which has hitherto not been mentioned, may now be brought forward. The hypothesis of complete formation demands that the defect in the rotational energy of the 'catalyst' or diluent component may be absorbed as infra-red radiation. In all that has gone before this defect has been supplied by raising the temperature, and the hypothesis cannot be considered as entirely justified unless it be proved that resolution of the complexes can be achieved by exposure to infra-red radiation. The fact that the most effective method of deactivating an activated phosphore and of releasing the whole of its phosphorescence is by exposing it to infra-red radiation adds a conclusive argument in support of the hypothesis.

It will be noted that there is a marked difference between the phenomena in photoluminescence and chemical reaction at temperatures above the upper limit, since in the former phosphorescence is no longer possible, and in the latter the reaction velocity is a maximum. This difference is due to the fact that a chemical reaction is the result of a single process of activation, and when the activated molecules are set free by the resolution of their complexes the reaction takes place immediately. The phenomenon of photoluminescence is the result of a two-stage process of activation, the second stage only taking place so long as the complex is in being. When the complex is no longer stable the second stage can no longer be achieved.

It has already been pointed out that in the photosynthesis of carbohydrates the activation to the high energy level necessary for the chemical reaction is effected in two stages, namely, partial activation in the absorption complex and completion by absorption of an energy quantum at a frequency in the visible spectrum. There is therefore a close analogy between this and the activation of a phosphorogen. Since there exists in the latter an upper temperature limit above which the second stage of activation does not take place, so it is to be expected that there must be an upper temperature limit above which no photosynthesis can take place. This is actually the case, since, as was shown in fig. 3, there is a rapid decrease in the yield of carbohydrates as the temperature is increased above 31° and the reaction falls to zero at about 48°.

This decrease in efficiency is a very remarkable fact, and, as is well known, it is observed also in the living leaf. It has long been a source of difficulty to plant physiologists and the generally accepted explanation

is that of F. F. Blackman, who postulates a second reaction due to an enzyme, superimposed on the first. In the laboratory experiments the Blackman reaction must obviously be absent, and in spite of this the results are remarkably analogous to those found in the living plant. The analogy is made still closer by the fact that the linear relation shown in fig. 3 gives the temperature coefficient of the laboratory photosynthesis between 20° and 30° as 1·54, whereas the value found in the plant is 1·6.

This, however, is by the way, for the analogy that is particularly striking is that between photosynthesis and photoluminescence, both of which have been found to have an upper and a lower temperature limit.

The success that has attended the application of the hypothesis of complex formation to three widely differing phenomena justify its general application to all thermal chemical reactions. This naturally leads to the view that every such reaction depends on the presence of a catalyst. There seems little objection to this because it is a fact familiar to everyone that chemical reactivity suffers a most remarkable decrease as all impurities are removed. It is perhaps a sweeping statement to make that no thermal reaction can take place in the complete absence of a catalyst, but the fact remains that in every case which has been accurately examined the reaction velocity is zero. In inorganic chemistry the most effective catalyst is water and H. B. Baker's work on the absence of reaction between dry substances is classical. It may be that this power of water is connected with its great ionising power towards inorganic salts, for it is possible that ionisation itself is the result of a complex between solvent and solute.

In general, it must be remembered that every chemical reaction has its own critical increment of energy, and this means that the reactant molecules must be raised to a definite energy level which is specific for the reaction required. The catalyst molecule must, therefore, be one which by forming a complex with the reactant molecule raises it to that energy level and no other. The possibility of the same molecules being raised to different energy levels has been established by absorption spectra, since by the use of different solvents it is possible in the case of many compounds to obtain them in different physical states as evidenced by different absorption bands. The integral relation has been suggested in photochemical reaction, namely

$$h\nu_0 = h\nu_1 + h\nu_2,$$

where $h\nu_0$ is the quantum absorbed at the visible or ultra-violet frequency characteristic of the reactant molecules in their initial state, $h\nu_1$ is the critical quantum of activation, and $h\nu_2$ is a quantum of fluorescence and also the quantum absorbed at the characteristic frequency of the activated molecule. If this relation be fully confirmed by further work, the different molecular states of one compound, proved by absorption spectra methods to exist in different solvents, will be directly linked up with the different chemically reactive states of that compound. The difficulty in postulating a series of catalysts which can induce different reactions of the same substance will then disappear.

We may now turn once again to the radiation hypothesis and take stock of the position. The protagonists of this theory, after enunciating

the principle of a single quantum of activation, took a further step and assumed that this quantum $h\nu_1$ could be absorbed when the reactant molecules in the absence of all catalysts were exposed to radiation of the frequency ν_1. They had no justification whatever for this assumption and it is germane to ask why the fact that no substance showed an absorption band at the critical frequency ν_1 was considered to be of no great importance. The phenomena of photoluminescence afford very convincing evidence of the existence of molecules in different states of activation, each with its own critical quantum of activation. They also establish the fact that although this critical quantum can be radiated as phosphorescence, the molecules cannot absorb it at the critical frequency. Although the activated states responsible for phosphorescence are characterised in general by their very long life periods, the fact that the activation cannot be achieved by a simple absorption process may be accepted as a proof of the incorrectness of the assumption made in the second part of the radiation hypothesis. This evidence is independent of the *ad hoc* criticism by Lindemann and by G. N. Lewis. At the same time the evidence is in favour of the reality of the critical quantum of activation, which is the fundamental tenet of the radiation hypothesis. An enquiry into the possible methods of activation whereby a reactant molecule can gain its critical quantum was made necessary, because the theory of activation by collision has not met with complete success, as no proper relation with photochemical activation has been established.

Photoactivation of a molecule results from the absorption of a single quantum of energy at a frequency $h\nu_0$ in the visible or ultra-violet which is specifically characteristic of the molecule in its initial state. This quantum $h\nu_0$ is invariably larger than the critical quantum of activation $h\nu_1$, and this is the explanation of Stokes' law in photoluminescence. The difference between the two quanta is radiated during the activation process as a single quantum of fluorescence, so that

$$h\nu_0 = h\nu_1 + h\nu_2.$$

The same relation has been found to hold in a photochemical reaction and fluorescence is an indication of the formation of an activated state of the molecules. In the absence of fluorescence the expected photochemical reaction does not occur, and it may be deduced from this that the quantum efficiency will approximate to unity (in the absence of the chain mechanism) when fluorescence is fully developed, and very small indeed or zero in the absence of any measurable fluorescence. The expression, given by W. C. McC. Lewis, for the observed heat of a reaction

$$Q = Nh(\nu_y - \nu_x),$$

where $h\nu_y$ and $h\nu_x$ are the critical quanta of activation of the reactant and resultant molecules, respectively, has been extended to photochemical reactions. In a monomolecular reaction which is photochemical and reversible the observed heat of reaction is given by

$$Q = Nh(\nu_r - \nu_0),$$

where ν_0 and ν_r are the characteristic ultra-violet frequencies of the reactant and resultant molecules, respectively.

A second method of activation has been suggested, namely the formation of a complex between a molecule of the reactant and a molecule of a catalyst, in which the former has gained its critical quantum of activation at the expense of the rotational energy of the latter. Such a complex will be stable and will only be resolved into its components when the defect in rotational energy of the catalyst molecule has been restored, this being possible by the absorption of infra-red radiation. The result of this resolution will be the setting free of the reactant molecule in the activated state. It follows that the complex will only be stable below a certain definite temperature. As the temperature is progressively raised the stability will be progressively decreased, until a second temperature limit is reached, at which the complex has no stability. At this upper temperature the reaction velocity will be a maximum. The observations of absorption spectra afford strong support to this hypothesis of complex formation. The particular case of the phenolic ethers has been examined in detail, and it has been found that in concentrated sulphuric acid solutions a stable state exists at 15°, in which the ether molecules have received their critical quanta of activation. A progressive increase of temperature causes a progressive increase in reaction velocity.

In applying this hypothesis to all thermal reactions it is necessary to assume first that no reaction can occur in the absence of a catalyst. This assumption seems to be justified by the known effect of the removal of all impurities on the reaction velocity. In the second place it is necessary that the catalyst activate the reactant molecule to the energy level required and no other. That this is possible is established by absorption spectra observations, which show that the same molecules can be raised to different energy levels within the complexes formed with different solvents. In inorganic chemistry the problem is less complicated, since in the great majority of cases only one activated state is indicated; this activated state exists in general within the complexes formed with water.

In the field of photoluminescence the activation is a two-stage process, since phosphorogen molecules are already partially activated in their complexes with the molecules of the diluent. The existence of these complexes is proved by the absorption frequencies of the phosphorogen, which are nearer the longer wave-lengths than those of the same substance in the free state. By photo-activation the phosphorogen molecule within the complex is raised to a higher energy level, the process being attended by the radiation of a quantum of fluorescence. This higher energy state is stable since the complex still exists. It follows that there will be a temperature limit below which no phosphorescence can take place. As the temperature is progressively raised above this limit the intensity of the phosphorescence will progressively increase and the persistence will progressively decrease. When, by further increase in temperature, the region of complete instability is entered, the conditions for the special photo-activation no longer exist and all luminescence ceases. Not only are the two temperature limits of photoluminescence explained by the hypothesis of complex formation, but also the stability of the activated states.

The reaction whereby carbohydrates are photosynthesised from carbonic acid may be compared with the photo-activation of a phosphore,

the initial complex being an adsorption complex of carbonic acid and nickel carbonate. There should exist, therefore, a lower temperature limit below which the reaction will not take place; an intermediate temperature zone in which the reaction will take place with a definite temperature coefficient; and an upper limit of temperature at which all reaction again ceases. These three phenomena have been observed, and the photosynthetic and photoluminescent processes proved to be analogous. In the one the highly activated molecules undergo chemical reaction, in the other they emit their critical quanta of activation as visible radiation.

It may be claimed that the evidence brought forward from the three fields of photoluminescence, absorption spectra and chemical reaction constitutes a story that is not without interest. The one dominating influence in this story is the critical quantum of activation which has found its experimental verification. In laying down the pen of authorship I do so in the confident hope that a definite step has been gained towards a radiation theory of chemical reaction.

SECTION C.—GEOLOGY.

THE PALÆOZOIC MOUNTAIN SYSTEMS OF EUROPE AND AMERICA.

ADDRESS BY

E. B. BAILEY, M.C., LÉG.D'HON.,

PRESIDENT OF THE SECTION.

FOREWORD:—Geological time is so long that non-technical readers cannot hope to carry in their heads even the main elements of its chronology. The following memorandum is supplied for reference in connection with the present address.

The major time divisions are of very unequal value. They run as follows, beginning with the oldest:

Precambrian: Primary or Palæozoic; Secondary or Mesozoic; Tertiary or Cainozoic; Quaternary, in which we find ourselves living.

Palæozoic time is divided, beginning with the oldest, into: Cambrian; Ordovician; Silurian; Devonian (including Old Red Sandstone); Carboniferous; Permian.

Ordovician time is subdivided, beginning with the oldest, into: Arenig; Llandeilo: Caradoc (including Ashgill).

Silurian time is subdivided, beginning with the oldest, into: Llandovery; Tarannon; Wenlock; Ludlow; Downtonian.

Devonian time is subdivided, beginning with the oldest, into: Lower; Middle; Upper Devonian.

Carboniferous time is subdivided, beginning with the oldest, into: Carboniferous Limestone; Millstone Grit; Coal Measures.

In what may be called the Bertrand time-classification of folded mountain systems:

Caledonian includes all folded mountains developed in early Palæozoic times, not later than Devonian. The name is derived from Scotland.

Hercynian includes all folded mountains developed in later Palæozoic times, that is Carboniferous, extending into Permian. The name is derived from the Harz in Germany.

Alpine includes all folded mountains developed in Mesozoic and Tertiary times. The name is derived from the Swiss Alps.

GEOLOGISTS attach a deeper and more lasting significance to mountains than do geographers. They can dispense with such attributes as mere height and form, and can recognise as geological realities mountains that no longer show above the general surface of the ground. There are extensive districts in Belgium and France where the mountains of yesterday peer up at us through the valley bottoms of to-day; or where these same mountains have been visited only by miners who have sunk shafts to them, in search of coal, through overlying formations.

The mountains to which I am directing your attention are folded mountains, a product of lateral compression; and it is the contorted and ruptured condition of their component strata which stamps them with their enduring character. We find this character in the relatively

modern mountains of Switzerland, combined with elevation. We meet with it in the much more ancient and less exalted mountains of our own country, combined with unconformity. Such unconformity speaks to us of elevation brought low by erosion, coupled in many cases with actual subsidence. The evidence, carefully considered, justifies us in restoring to the ruined heights an original grandeur comparable to that of their proud successors.

I have just referred to two of the fundamental conceptions involved in our subject—lateral compression and unconformity. Their significance was early appreciated in the study of the Southern Uplands of Scotland. In 1812 James Hall suggested lateral compression as the cause of the 'convolutions' of the Silurian strata visible in the coastal cliffs of Berwickshire. He spoke of 'horizontal thrust,' and imitated the observed effect by the sideways crumpling of a pile of cloths. As for unconformity, its critical discussion represents one of the main achievements of Hall's master, James Hutton, Father of Modern Geology. Unconformity is a comprehensive word used by geologists to express an erosional gap in the stratigraphical sequence. Some unconformities are obscure and debatable; but unconformities that succeed periods of mountain folding furnish most impressive spectacles. Hutton long searched the Southern Uplands for a contact of the flat Old Red Sandstone and the steeply folded Silurian greywackes. His scientific imagination pictured in advance the relationship of the two formations, and he felt that its demonstration 'would add great lustre' to his Theory of the Earth. In 1787 he found his expectations fully realised in the banks of the River Jed, where horizontal Old Red Sandstone covers an eroded surface that truncates the steep bedding of underlying greywackes.

Hutton saw in the Jed exposures a buried mountain chain in process of disinterment. The mountain rocks have just been reached by the river, and are therefore restricted to the valley bottom; but they possess an inherent quality which will presently lead to a reassertion of something of their old predominance in landscape. The compressional forces responsible for mountain building tend to indurate the materials upon which they operate. They therefore exercise a potent though indirect influence upon the development of scenery, wherever and whenever folded mountains appear at the surface. Let us always remember that the beauty which characterises the mountain exposures of Britain has more to do with resurrection than survival. Most, if not all, of the folded mountains of our islands have been beneath the sea and covered by unconformable deposits at some period since the day of their plication. They owe their partial reappearance to subsequent upheaval and denudation. Erosion, busy at first, has stripped away much of the comparatively unresistant cover; now it lingers and permits the re-exposed mountain rocks to stand for a while as uplands overlooking adjacent plains.

The same general story holds in countries other than our own. Accordingly, certain old mountain areas, such as the Highlands of Scotland and the Harz of Germany, were recognised by their inhabitants without help from geologists; but when Suess and his disciples came to synthesise mountain chains from exposed fragments, they naturally had to supply names for their discoveries.

FIG. 1.—Tectonic Map of Europe.

The ornamented regions (Baltica, Laurentia, etc.) have remained unaffected by mountain-folding since Precambrian times. Their Precambrian outcrops are shown by ticks, Cambrian and later by stipple. Contractions are used for Black Forest, Edinburgh, Girvan, Jämtland, Liège, Stonehaven, Trondhjem, Valenciennes, Wicklow.

Two factors are involved in the geological classification of folded mountains, namely date and position. One half of the surface of Europe has escaped mountain deformation since the dawn of the Cambrian. This stable area, which we may call Baltica, has roughly the form of an equilateral triangle. Two of its boundaries diverge from South Wales: the one follows approximately the Norwegian-Swedish frontier; the other, highly complex in its development, passes south of London and Berlin and north of the Crimea and Caucasus. The third side of Baltica is furnished by the Urals, but of this I do not propose to speak.

Let us look a little more closely at Baltica, because it will repay us when presently we cross the Atlantic. On the north and west sides of the Baltic Sea the prevalent rocks exposed at the surface are Precambrian and most of them are crystalline. This part of Baltica, Suess has called the Baltic Shield, to convey the idea of a gently convex surface. Its immunity from Cambrian and later folding movement is inferred from the uniform testimony of its girdle of almost undisturbed Palæozoic outcrops. The rest of Baltica lies cloaked in sediments ranging from Cambrian to Tertiary. It has been named the Russian Platform, and its western continuation probably extends through Denmark into the English Midlands.

Two Palæozoic mountain chains meet in South Wales about the western angle of Baltica. In 1887 Suess named the older of them Caledonian, out of compliment to Scotland. It runs north-east and its folded, cleaved and broken rocks appear at the surface in many parts of the British Isles, in most of Norway and along much of the Swedish frontier. They frequently include marine representatives of the Cambrian, Ordovician and Silurian; but the Devonian, where developed within the Caledonian belt of Britain and Scandinavia, and often in adjacent districts, is of continental or, in other words, of Old Red Sandstone facies; and is later than the more violent of the mountain disturbances.

Great Britain is unique in being crossed by both margins of this Caledonian Chain. Under the North Sea the old mountains are completely submerged, and where they reappear in Scandinavia it is with their north-western edge still hidden off the coast of Norway.

In Shropshire and Radnor, where England and Wales meet, Lower Old Red Sandstone follows conformably on Downtonian that forms the top of the Silurian; and the important unconformity of the district is between Silurian and Ordovician. It is an unconformity that is rather more striking upon a map than in field exposure, for here we stand at the south-east margin of the Caledonian Chain, and there has been comparatively little folding of Palæozoic rocks.

Proceeding north-westwards, we soon enter a mountain element characterised by intense post-Silurian unconformity. On the far side this element is bounded by an ill-determined north-east line that passes close to Girvan and Edinburgh, so that its cross-strike measurement is about 180 miles. Eastwards its rocks are hidden beneath comparatively undisturbed Carboniferous and later formations that occupy the surface from Shropshire to Northumberland. Westwards they delight our eyes in Wales, the English Lake District and the Southern Uplands of Scotland.

Silurian is widespread in this mountain element and shares in the intense corrugation and frequent cleavage of its Ordovician substratum. Lower Old Red Sandstone occurs in Anglesey and the Cheviots and between Girvan and Edinburgh, and is markedly later than the major deformation of the Silurian. Still, both in Anglesey and near Girvan, Lower Old Red Sandstone has suffered pronounced deformation, and in the former locality has actually been cleaved.

Near Girvan we find, in addition to the post-Silurian unconformity, another of intra-Ordovician date, sufficiently important to bring Upper Llandeilo conglomerates on to Arenig plutonic intrusions. This earlier unconformity disappears with amazing rapidity towards the south-east; but north-westwards it increases in scope, while in the same direction the post-Silurian unconformity fails.

The evidence for these propositions lies partly in the Southern Uplands and partly in exposures to the north-west. The interpretation of the Southern Uplands is one of the miracles of Science. We owe it to Lapworth, an English schoolmaster attracted to Galashiels by the charm of Scott's romances. During the seventies of last century Lapworth demonstrated that the hitherto despised graptolites furnish an extraordinarily sensitive time-scale for Ordovician and Silurian stratigraphy. This led him on to the discovery that many of the rock groups that pass with broken complication through the tightly compressed steep isoclinal folding of the district change profoundly in thickness and character from south-east to north-west. The total thickness of the Upper Llandeilo, Caradoc, and Llandovery at Moffat in the centre of the Southern Uplands is given by Peach and Horne as 220 feet, consisting of black graptolitic shale and unfossiliferous mudstone. At Girvan, which is only 25 miles to the north-west in cross-strike measurement, these same formations are reckoned as more than 4,800 feet thick, and their constituents include conspicuous conglomerates, grits, flags, grey shales, shelly beds and one 60-foot limestone, in addition to subordinate intercalations of black graptolitic shales. Careful examination of many intermediate exposures, afforded by folds one behind another, has allowed the details of this transformation to be deciphered. The coarse deposits mark an approach to a coast line lying to the north-west, and their material contains much recognisable debris of Arenig cherts, lavas and intrusions that must have formed part of a land surface in that direction. At each successive period, starting with Upper Llandeilo, the coarse sediment pushed farther and farther south-eastwards across the sea bottom. In Tarannon times it had reached beyond Moffat; and to find exposures of a complete black graptolitic representation of this particular period one has to travel to the English Lake District.

When it is remembered that this variation of facies is combined with incessant isoclinal packing and accompanying dislocation, and that the grassy Southern Uplands are as devoid of geological features as are the Chalk Downs of Sussex, Lapworth's triumph fully exonerates the failure of his predecessors.

From the great thickness of shallow-water marine sediments, deposited during Ordovician-Silurian time near the northern edge of the Southern Uplands, we may deduce a corresponding long-continued subsidence of

the sea bottom. Subsidence preparatory to mountain upheaval is a widely recognised phenomenon, and further instances will be considered in the course of this address. Meanwhile let us resume our journey north-westwards across the Caledonian Chain.

According to limited evidence at Lesmahagow in Lanarkshire, on the Girvan-Edinburgh line, and at Stonehaven, on the Highland Border, we immediately pass into a distinct mountain element characterised by absence of post-Silurian unconformity. At both localities, which unfortunately lie some forty miles apart in cross-strike measurement, the base of the Lower Old Red Sandstone is seen to rest conformably on Downtonian. At Lesmahagow this Downtonian is followed downwards by Ludlow and Wenlock; and then exposures cease. At Stonehaven the Downtonian, 2,750 feet thick, reposes with violent unconformity on greatly disturbed Cambrian, or possibly Arenig. This Stonehaven unconformity may reasonably be regarded as an exaggeration of the intra-Ordovician unconformity already encountered at Girvan.

The Cambrian, or perhaps Arenig, rocks at Stonehaven belong to the well-known Highland Border series of pillow-lavas, cherts and shales. They have become doubly interesting of late years since Peach and Campbell and Jehu have made known their fossils. Barrow had previously interpreted the Border series as steeply overthrust by the generally schistose Dalradian rocks of the Southern Highlands; and such a view seems reasonable in the type section of the North Esk. On the other hand, Gunn has practically demonstrated its superposition on the Dalradians in the Island of Arran. Here no sharp line of metamorphic difference has been detected; but Gregory claims an unconformity based on identification of pebbles.

Having reached the Highland Border we are confronted with many difficulties. Following Teall, I am prepared to say that we do not know how far the Highland Schists are Precambrian. Most observers, like Horne, Barrow and Gregory, regard even their metamorphism as Precambrian; but this view was always strongly combated by Peach. Whatever their age, the Highland Schists admittedly lie within the Caledonian mountain belt, for they are bordered on either side by intensely moved Cambrian (perhaps Ordovician) fossiliferous rocks. They also received additional elevation a little before and during Lower Old Red Sandstone times, as is witnessed by a south-eastern fringe of tilted Lower Old Red Sandstone (with Downtonian) conglomerates that remind one irresistibly of the nagelfluh of the Swiss Mollasse. Moreover they were the site of great volcanoes and of granitic intrusions during Lower Old Red Sandstone times in a manner that co-ordinates them with the folded Ordovician-Silurian areas of the South of Scotland and the Wicklow Mountains of Ireland.

I do not propose to occupy this address with a recitation of our Highland problems, but venture to touch upon three topics of particular interest.

(1) Barrow, beginning in 1893, has drawn contours of metamorphic intensity across much of the south-eastern Highlands. His has been a pioneer's task and has anticipated anything of the kind attempted in other countries. To-day it is finding very valuable application in the south-western Highlands at the hands of Tilley and Elles.

(2) Clough, Crampton and Flett have described a wonderful aureole of contact-metamorphism partially surrounding the Inchbae augen-gneiss of Ross-shire. The history of the district is as follows: A great thickness of sediments accumulated; a large mass of porphyritic granite intruded into these sediments and hornfelsed them for a considerable distance from the contact; the whole, at some later period, became involved in conditions of stress and temperature suitable for high-grade regional metamorphism; the unbaked sediments yielded and were altered to para-gneisses; even the porphyritic granite was for the most part changed to augen-gneiss; but the hornfelsed sediments in large measure moved *en masse* without internal deformation, so that, though crystalline, they retain to this day many of the minutiæ of their original structure, such as grains, bedding, ripple marks and suncracks.

(3) Continuing the work of Clough and Maufe, I have been fortunate enough to trace out refolded recumbent folds in several districts of the Southern Highlands. These folds are many miles in cross-strike extent, and their limbs have suffered inevitable disruption with the production of fold-faults or 'slides.' The investigation of these structures was begun at Ballachulish and has since proceeded far across the country. The available evidence has not in any way been exhausted, and the promise of future discoveries is extremely bright, especially towards Banffshire where Read is at present working.

The Caledonian portion of the Scottish Highlands is 120 miles broad in the east, but narrows greatly towards the west. Its north-west border is furnished by the Moine thrust-zone. It will be convenient to defer consideration of this great structure-line until we have taken a brief look at the Scandinavian development of the Caledonian Chain, for in many respects the Moine thrust-zone and its foreland belong rather to American geology than to European.

The most impressive geological phenomenon in Scandinavia is the marginal over-riding of Baltica by the Caledonian mountains. In Britain, where the Welsh Border shows the contact of these two structural elements, it is a mere matter of foot-hills grading into foreland, it is an affair of outposts. True, the Carmel Head Thrust of Anglesey is an important structure of post-Llandovery pre-Devonian date—Greenly gives it three miles of displacement as a minimum and twenty miles as a probability—but this thrust is separated from Baltica by the Welsh zone of folding. In Scandinavia the mountains often appear with startling abruptness, thrust far out over the edge of Baltica.

The type district for studying the great Scandinavian overthrust is the province of Jämtland. Here comparatively wide exposures of fossiliferous Cambrian, Ordovician and Silurian pass north-westwards below the over-riding mountains. In the south-eastern part of their outcrop, the Cambrian and Ordovician total only about 300 feet in thickness, of which the greater part is Orthoceras-limestone of Middle Ordovician age; and the Silurian also is of very moderate dimensions. North-westwards, that is towards and under the mountains, the Cambrian and Ordovician swell mightily, and show an accession of sandy material which is reminiscent of the north-westward facies-change traced by Lapworth in the Southern Uplands of Scotland, although, of course, the position relative to the Caledonian margin is very different.

The Jämtland Cambrian rests upon crystalline rocks, mainly granite or porphyry. To the south of the province, however, there is a great development of a fl t-lying Precambrian formation (sandstone, &c.) called Sparagmite, which is of later date than the granite and porphyry and is often compared with the Torridonian of the Scottish North-west Highlands.

The Cambro-Silurian succession of the Jämtland foreland is undisturbed in the south-eastern part of its exposure. Gradually, north-westwards, this tranquillity is replaced by isoclinal folding, small-scale thrusting, and intense distributed shearing, unaccompanied by any marked development of metamorphic minerals. Above lies the great Scandinavian thrust-mass or 'nappe,' the cause and origin of all the trouble.

The contents of this over-riding 'nappe' are various; in the main they consist of metamorphosed sediments, which have been somewhat provisionally divided into (1) Precambrian, correlated with Sparagmite, overlain by (2) early Palæozoic. In both sets of rocks the metamorphic grade increases strongly towards the north-west, but there is good, though not undisputed, evidence that much of the crystallisation of the Precambrian part of the 'nappe' is of Precambrian date. An important detail, that everybody admits, is the frequent occurrence of recognisable scraps of crushed Precambrian granite and porphyry along the actual thrust.

The 'nappe' lies with broad undulations that make it virtually flat over a vast stretch of country. In consequence, erosion has given an extremely sinuous eastern margin to the portion that remains connected with the 'root region' to the north-west. Moreover, in front of this intricate margin there are great outliers or 'klippes,' the largest of which measures 30 by 10 miles; while behind there are elongated anticlinal 'windows' of comparable magnitude, in which we obtain circumscribed exposures of the buried foreland. Altogether we are furnished with a wonderful opportunity for measuring the distance that the mountain region has been driven forward over Baltica. When, in 1888, Törnebohm first propounded his overthrust theory of the Scandinavian Chain, he mentioned sixty miles as a minimum displacement and compared this estimate with the half-mile of overthrusting previously described by himself from Dalsland and with Peach and Horne's ten miles from the North-west Highlands of Scotland. In 1896, by which time he had received important help from Högbom, he was able to demonstrate that the Scandinavian thrusting exceeds eighty miles. One is amazed by the scale of the phenomenon thus elucidated practically single-handed. Törnebohm built upon his own explorations and corrected his own initial mistakes. Jämtland as regards area is comparable with Switzerland, but in Törnebohm's field of inquiry it occupied merely the position of a province. A big man in body and mind, he was faced with a task that required exceptional equipment. Högbom, writing shortly after Törnebohm's death in 1911, recalled 'how sometimes his assistants ran away from him because they could not endure the fatigues or follow him when with his great strides he rambled over the mountains.' These words read strangely like a parable, for to-day Scandinavian geologists have turned back to experiment for themselves with all the philosophies of double-

folding and the like. Törnebohm stands out the Giant of the North, of such a stature that the generation that has succeeded him has been unable to maintain his conquests.

The interior of the Norwegian mountains must not delay us, vitally interesting though it be. We can only mention that a little west of Jämtland lies the great Trondhjem field of folded early Palæozoic rocks, locally eighty miles broad. These rocks have yielded Ordovician and Lower Silurian fossils, but differ profoundly in original characters from the contemporaneous formations of the Jämtland foreland. They are moreover in many instances highly metamorphic, with actinolite, garnet and biotite. On this point there seems to be complete agreement among Scandinavian geologists. In our own country there is a tendency to associate the idea of metamorphic schists with a Precambrian date ; but it should be remembered that in the Alps it is well established that belemnites and other resistant Mesozoic fossils can be hammered out of garnetiferous mica-schist.

On returning to the North-west Highlands of Scotland, we arrive at the opposite margin of the Caledonian Chain to that studied by Törnebohm in Jämtland. A British audience knows full well the history of discovery in this wonderful region. At an early date Murchison and Geikie recognised schists as superimposed on the fossiliferous Durness succession and considered them to be a later conformable deposit, metamorphosed *in situ.* Nicol, however, thought that a steep dislocation separated the two sets of rocks. Callaway at last, in 1883, realised an ' overthrow ' locally ' more than a mile in width,' while Lapworth in the same year published his in many ways illuminating *Secret of the Highlands.* It is necessary, in common justice, to recall that this paper was merely a preliminary account and that subsequent exposition of his views was prevented by a breakdown in health caused by the excitement of discovery. In 1884 Peach and Horne were able to show that the Moine Thrust-mass or ' Nappe ' has travelled north-west through a minimum distance of ten miles. Their report produced a profound impression, the more so because it was accompanied by a candid recantation on the part of Archibald Geikie, which proved as helpful to tectonic science in 1884 as Heim's somewhat comparable letter on the Alps in 1902.

Peach and Horne, it may be added, worked in an atmosphere of detachment. Most Alpine geologists of the day, Rothpletz excepted, had rather exaggerated the idealisation of thrusts as vanished limbs of overfolds —and in this respect they were followed by Lapworth. The generalisation is undeniable ; but insistence upon it often leads to artificial presentations of comparatively simple phenomena. Peach and Horne merely reproduced what they saw in Nature, and left it at that. Their lucid and beautifully illustrated descriptions, dating from 1884, 1888, and 1907, have, in Suess' words, ' rendered our northern mountains transparent.'

The fossiliferous sediments of Durness, over which the Moine crystalline schists are thrust, rest upon a flat-lying Precambrian sandstone formation known as the Torridonian, and this in turn upon Lewisian Gneiss. The Durness sediments are of Cambrian and probably Lower Ordovician age. They are essentially a quartzite-limestone (largely dolomite) succession, and in lithological character and fossil content they belong much more

nearly to North America than to the rest of Britain. This fact was recognised in the fifties of last century by Salter when he described C. W. Peach's collections from the Durness Limestone. He had already had the good fortune of familiarising himself at first hand with Canadian material.

There is no chance of unravelling the original relations of the American and British facies of the early Palæozoic in Scotland, or even in Norway, where Holtedahl has recently recognised the American facies of the early Ordovician on the Island of Smölen, west of Trondhjem. Let us therefore set sail for America.

The Atlantic seaboard of North America,[1] southwards from Newfoundland, is constituted of Palæozoic mountains, partially concealed, it is true, from New York to the Gulf of Mexico beneath a coastal spread of Cretaceous and Tertiary rocks. American geologists call their ancient mountains the Appalachian System. To European eyes they appear as a complex of two systems, rather than as a single system; but for the moment we may let this pass. Beyond the Appalachian Mountains lies an enormous interior region, the Laurentia of Suess, that, like Baltica, has remained unaffected by folding since late Precambrian days. Laurentia, again like Baltica, has two main elements: a vast exposure of Precambrian rocks, the Canadian Shield, recalls at once the Baltic Shield; while the Great Plains, with their cover of Cambrian and later formations, correspond with the Russian Platform, and are bounded on the south-west by a Mesozoic-Tertiary cordillera. The comparison[2] may be pushed to matters of detail, for a narrow offshoot of flat Palæozoic rocks extends from the Great Plains along the St. Lawrence Lowlands to separate the Canadian Shield from the Appalachians, just as a strip of flat Palæozoic rocks runs up through Jämtland to separate the Baltic Shield from the Scandinavian portion of the Caledonian Chain.

With so many points of comparison, it is not surprising to find that we can go farther still. The age and relations of the portion of the Appalachian complex, which borders the St. Lawrence Lowlands, justifies our grouping it with the Caledonian System. It was Marcel Bertrand who, in 1887, saw that the Appalachian Mountains, as a whole, could be partitioned among the two great Palæozoic systems that, on our side of the water, meet in South Wales. In Newfoundland, Canada and northern New England the Appalachian Mountains belong to the Caledonian System, in the sense that their main movements were completed before the close of the Devonian period. We may quote from Young in his *Geology and Economic Minerals of Canada* published by the Canadian Geological Survey in 1926: 'Before the close of the Devonian period,' he says, 'the Appalachian and Acadian regions were uplifted and the strata folded and faulted, and

[1] Last year I had the privilege of sharing, with my friend Collet, in the Princeton Summer School excursion organised by Field, and anything I have to say on American Geology is directly or indirectly the result of this experience.

[2] When in *Nature*, November 5, 1927, I developed the idea that 'the North American Continent is, broadly speaking, a magnified mirror image of much of Europe,' I was unaware how closely I was following O. Holtedahl in 'Some points of Structural Resemblance between Spitsbergen and Great Britain, and between Europe and North America,' *Avhandl. Norske Videnskaps-Akad.*, Oslo, I, 1925, No. 4.

FIG. 2.—Tectonic Map of North America.

The ornamented region (Laurentia) has remained unaffected by mountain-folding since Precambrian times. Its Precambrian outcrops are shown by ticks, Cambrian and later by stipple. Quoted from *Nature*, 1927, p. 674.

invaded by granite batholiths'; and again: 'The major part of the folding and faulting of the Palæozoic and late Precambrian strata took place during the Devonian interval of orogenic disturbances.'

There is, it must be admitted, a minor, perhaps only an apparent, delay in the Caledonian history of Canada as compared with that of Britain. In Canada certain important marine limestones that are involved in the mountain folding are, according to present-day terminology, referred to the Lower Devonian; while the Gaspé Sandstone, that seems to play a rôle comparable with that of our Lower Old Red Sandstone, is generally spoken of as Middle Devonian. Perhaps, as already said, this lack of harmony may be only apparent, for the Gaspé Sandstone agrees closely in its flora and fish fauna (if we include the Campbellton fishes) with our own Lower Old Red Sandstone. Indeed, not many years ago, the Gaspé Sandstone was treated by Williams and others as Lower Devonian. It was transferred from Lower to Middle by Clarke and Kayser on the basis of comparisons between the marine successions of America and Rhineland. Possibly we shall some day regain the correlation of the Gaspé Sandstone with our 'Lower' Old Red Sandstone by accepting Barrois' transference of our Downtonian from Silurian to Devonian.

Let us now go back for a moment to 1843, when Logan started the Geological Survey of Canada. By this time Hall and his colleagues had already determined the main stratigraphical features of the flat-lying Palæozoic rocks of Laurentia as exposed in the western portion of New York State. The succession there starts with Potsdam Sandstone of Upper Cambrian date, and continues upwards through a long quasi-conformable sequence into the Carboniferous of Pennsylvania. Logan had no difficulty in applying Hall's classification to the rocks of the St. Lawrence Lowlands; but at the south-eastern margin of these lowlands, along the course of the Champlain and St. Lawrence, he saw the familiar Ordovician of Laurentia passing beneath folded mountain-rocks, that at first seemed unidentifiable, whether on the score of lithology or fossils. Faced with this difficulty he was, for several years, content to date the mountain formations by the law of superposition. So long as they yielded only a few scattered fossils, this seemed quite reasonable. Barrande, looking from across the Atlantic, might claim an occasional trilobite as of Cambrian date; but, naturally, local observers could not understand the sanctity that Barrande attached to trilobite successions, remembering the theory of 'colonies' which he himself had introduced to account for graptolite recurrences. In 1860, however, fossils were rediscovered in abundance in the Lévis exposures that overlie the top of the Ordovician in the neighbourhood of Quebec. Many of these fossils were of Cambrian, others of early Ordovician types. The number of forms was so great that to apply the theory of 'colonies' to account for their position would have been tantamount to throwing to the winds all faith in palæontological stratigraphy. Accordingly Billings, the Palæontologist of the Canadian Geological Survey, transferred the Lévis rocks to a low position in the Ordovician, where they remain to this day.

Billings was working in close touch with Logan, who thoroughly appreciated the significance of this stratigraphical revolution. On December 31, 1860, Logan addressed a long letter to Barrande, and told

him how he had been forced to recognize a zone, situated on the mountain front, where older rocks are habitually overthrust upon younger. His knowledge of the country was so thorough that he did not merely indicate the position of the postulated thrust near Quebec, but laid down its course all along its Canadian outcrop from Lake Champlain to the extremity of Gaspé. On this account the Champlain-St. Lawrence thrust-zone is often spoken of as the Logan Line.

Logan was, of course, only applying a familiar principle; for, in the States, thrusts had been described by the brothers Rogers as early as 1842, and, in the Alps, by Escher in 1841. Still there can be no question that Logan's 1860 letter to Barrande furnishes one of the main landmarks of tectonic science.

Almost as soon as Logan recognised the north-westward frontal thrusting of the Caledonian Mountains of Canada he realized that it followed a much older line of slope, leading down south-eastwards from the platform of Laurentia to the comparative depths of the Caledonian sea bottom. He based this conception on the fact that the thrusts often bring forward thick developments of fossiliferous Palæozoic sediments that are older than anything in the local unmoved Palæozoic succession of the over-ridden foreland. For instance, near Quebec the thrust-masses include thick Lower Ordovician sediments, and very probably Cambrian as well, whereas the unmoved Palæozoic succession commences with Middle Ordovician resting directly on Precambrian gneiss.

Logan gave his theoretical slope a double function. First of all it had to act as a boundary to early sedimentation, and then as a guide to later thrusting and folding :—

'The resistance offered by the buttress of gneiss,' said he, 'would not only limit the main disturbance; but it would probably also guide or modify, in some degree, the whole series of parallel corrugations, and thus act as one of the causes giving a direction to the great Appalachian Chain of mountains.'

There is, however, another aspect of Logan's Slope that has not, I think, attracted sufficient attention. This slope, when completely submerged, seems to have furnished a dividing line between clear-water Ordovician limestones (American facies), that grew on its top to the north-west, and muds and sands (Caledonian facies), that, creeping from the opposite direction, came to rest at its foot. The fossils of the two sets of deposits are as distinct as the rocks themselves, and this has led certain distinguished palæontologists to postulate continuous land barriers, or isthmuses, separating the two fields of accumulation. On the other hand I think it can be established that the limestone of the one field has repeatedly landslipped down upon the mud of the other; in which case the division cannot have been an isthmus, but merely a submarine slope.

The conception of the Logan Slope that I am now about to present is a slight modification of Logan's original. Let us picture the slope, not as a rigid feature of Precambrian date, eventually obliterated by Palæozoic sedimentation, but as tectonic in origin and intermittently renewed by hinged subsidence. Earthquakes connected with the intermittent renewal were probably responsible for the landslips to which I have just alluded. It is well known that most of the major earthquakes

of to-day originate on submarine slopes, and that important submarine landslips precipitated by such earthquakes have been described, for instance, in connection with the Tokyo disaster of 1923. Of late years Kendall has reawakened British students to the possibility of recognising earthquake phenomena in the records of the past. I believe that a story of recurrent earthquakes is written in the submarine landslip-deposits of the Logan Slope. These deposits show the following characteristics :—

(1) Through a succession of geological ages (Cambrian to Middle Ordovician) they repeatedly occur along a particular tectonic zone.

(2) They are often interbedded among shales of Caledonian facies, whereas their material consists mainly of limestone blocks and isolated shells of American facies.

(3) Walcott has shown that in many instances the fossils contained in the blocks are identical with the isolated fossils of the matrix ; the deduction is that the blocks are often little older than the containing deposit.

(4) The internal arrangement of the deposits is tumultuous and unbedded.

(5) Some of these boulders are gigantic. I have seen one 60 feet long that has ploughed deep into underlying shale. Other boulders have been described 150 feet long.

Various authors have attempted to explain these deposits as glacial, but Ruedemann has stated in regard to an example of Trenton date (Middle Ordovician) that 'the action of coast ice may, in the writer's judgment, be excluded here on account of the presence of the Trenton fossils, including corals, in the matrix.' Ruedemann's judgment may be applied on similar grounds to many instances of earlier date. It is absolutely certain that most of these tumultuous deposits accumulated spasmodically during the growth, close at hand, of the great Ordovician limestone of Laurentia. Geographical exploration, in keeping with chemical physiology, assures us that important limestones are products of warm seas. It seems incredible that this Ordovician limestone platform, during its life-history, should have been intermittently exposed to the ravages of ice-floes, or have become the temporary site of an actual ice-sheet.

If now we cast our minds back to the change of facies that Lapworth recognised in the Southern Uplands of Scotland we find it on the whole of more gradual type than that characteristic of Canada. In the Southern Upland sea mechanical sediment travelled down a tectonic slope, and change of facies depended upon the arrest of coarse material by deep water. In the Canadian sea mechanical sediment reached the foot of a tectonic slope up which it was unable to climb. In both cases we notice subsidence preceding mountain elevation. This has long been a favourite idea with tectonists. It had its beginnings in a publication of Hall's on the Appalachians, dated 1859. Its subsequent development is due more especially to Dana and Haug.

We must now recross to Europe, there to get in touch with the later of the two great Palæozoic chains that meet in South Wales. In 1887 this later chain received a double name from Suess, who distinguished along its course a couple of congruent mountain arcs with an inflectional junction

of their fronts (syntaxis) near Valenciennes on the Franco-Belgian border. The eastern arc he called Variscan, the western Armorican. The names are based on the Latin for the Bavarian town of Hof, *Curia Variscorum*, and for the French province of Brittany, *Armorica*. The meeting of the two arcs near Valenciennes is closely comparable with the meeting of the Carpathians and Alps near Vienna.

The date of the Armorican and Variscan folding varies somewhat according to locality, but lies either within, or at latest shortly after the close of, the Carboniferous. Bertrand, publishing the same year as Suess, classed these mountains on a purely age basis, as part of his Hercynian System (called after the Harz). Unfortunately Bertrand's name Hercynian was preoccupied ; but I propose to use it in his sense in the present description.

The Hercynian Mountains of Western Europe are on the whole less continuously exposed than the Caledonian. The eastern front of the Variscan Arc is traceable at the foot of the Sudetes bordering the Upper Silesian coalfield that lies north of the Carpathians. From this point it is lost sight of for a long stretch, but reappears, from beneath the North German Plain, in the Ruhr coalfield of Westphalia. Westwards its continuation passes along the Belgian coalfield, where it is very well known, partly in surface exposures, partly in mining operations. Across the French border it joins the front of the Armorican Arc which has been traced, mostly underground, as far as the Pas de Calais coalfield. It is still buried south of Dover, but comes to the surface again in the Somerset and South Welsh coalfields, and is clearly exposed across the south of Ireland.

The course of this Hercynian front, where hidden, can often be inferred from trend lines in some neighbouring exposure of the interior. The main gap in the evidence, as a whole, is due to the Mesozoic and Tertiary cover that reaches from near Bristol, by the Isle of Wight, the Channel and the Paris Basin, onwards to the Juras. There is, however, no doubt that the Palæozoic and older exposures of South Wales, Devonshire, Brittany and the Central Plateau, on the one side, belong to the same mountain system as those of the Ardennes, the Vosges and the Black Forest on the other. In between the mountains are buried, not discontinuous.

The interior of the European Hercynian Mountains developed earlier than their northern periphery. At the close of Dinantian times, that is a little earlier than our Millstone Grit, much of the interior region yielded freely, for the last time, to mountain deformation ; whereas in the peripheral belt the main folding took place at some date towards the end of Coal Measure times. The contrast between the two portions of the chain is particularly striking if we compare the Saar Coalfield, on the south side of the Ardennes, with that of Belgium, on the north. The Coal Measures at Saar belong to the Hercynian interior region and are violently unconformable to folded Devonian ; whereas those of Belgium complete a conformable sequence extending up from the Devonian, and have shared in the corrugation and overthrusting of the latter. This condition of affairs reminds us of the two stages in the Caledonian folding of southern Scotland, where the date of folding depends upon position with reference to the Girvan-Edinburgh line.

A further complication is encountered in the Variscan Arc, if we look behind the commencement of Carboniferous time. We then find that the frontal line of the Variscan Arc occupies a median position as regards a local Caledonian arc that is recognisable in much of Belgium and southern Germany. Actually within the breadth of this early arc there is a great unconformity between Silurian and Devonian; whereas in the concavity to the south there is conformity, as exemplified in Bohemia. The limits of the Belgio-German Caledonian arc are very imperfectly known. It may, for instance, connect westwards, through Cornwall, with the main Caledonian Chain of Britain and Scandinavia.

The Franco-Belgio-German coalfield at the northern front of the Hercynian Mountains has long provided a favourite theme among tectonists. As far back as 1832 Dumont published a map with sections elucidating the isoclinal folding, but not the thrusting, of the Liège district in Belgium. He emphasised that 'one cannot employ dip to establish the relative age of primordial rocks.' He understood the position so clearly that he defined 'basins' and 'saddles,' not by the inclination of their marginal exposures, but by the downward or upward direction of their convexities. Having satisfied himself of the basin arrangement of the Coal Measures of his district, he worked outwards into the older rocks, and made substantial progress in zoning what we now call the Lower Carboniferous and Devonian. The referees who crowned his memoir for the Brussels Academy remarked that his work demonstrated violent folding with reversal, and that it suggested the effect that would follow from 'the gliding of a section of the earth's crust down an inclined plane with resultant lateral pressure' upon the country standing in the way. I do not think that any other country can boast of so advanced a tectonic study of such early date.

In 1849 H. D. Rogers was able to point out that the district presented 'precisely analogous features . . . [to those] which had been observed [by himself] in the Appalachians.' In 1877 Cornet and Briart, and in 1879 Gosselet, announced large-scale over-thrusting, the first of the kind to be recognised in European Palæozoic chains. Peach and Horne, it will be remembered, published on Scotland in 1884, and Törnebohm on Scandinavia in 1888.

A peculiar interest attaches to Gosselet's paper, for Bertrand in 1884 made it the basis of his famous comparison between Belgium and the Alps, and derived from it conceptions of much more extensive thrusting in the latter region than had hitherto been imagined. Bertrand's boldness has since been justified by Schardt's 1893 interpretation of the Prealps and all the marvellous consequences that have flowed therefrom.

I do not propose to go into detail regarding the marginal northward thrusting of the Hercynian Chain. It is of the same type, though not, in my opinion, so extensive, as the Caledonian thrusting of Jämtland, Scotland and Canada. Of recent years much the most delightful addition to our knowledge of the ground has been afforded by Fourmarier's 1905 interpretation of the Window of Theux, south of Liège. The frame of the 'window' consists entirely of Cambrian and Lower Devonian, whereas the 'window' exposure, some eight miles broad, shows, in addition, every group from Middle Devonian to Middle Carboniferous. The boundary of

the Theux outcrops is manifestly a dislocation, and early workers explained the local occurrence of the relatively late formations (Middle Devonian to Carboniferous) as due to preservation within an incomplete cauldron-subsidence. Fourmarier, however, by careful comparison of facies showed that the rocks of the surrounding country have travelled northwards relatively to those of the Theux exposure. To account for this horizontal displacement he necessarily interpreted the boundary dislocation at Theux as a low-angled thrust, cut through by erosion. He also identified the newly recognised thrust with the Eifel Thrust, well known in the country to the north. Before long Fourmarier's views were dramatically established by boring. The Carboniferous outcrop at Theux is separated by Devonian hills, three miles wide, from the exploited coalfield to the north. This separation has been proved to be merely superficial. Two deep bores, put down on Fourmarier's advice, pierced the Devonian and penetrated far into underlying Carboniferous. No coal seam was discovered, but the result was very justly hailed as a signal triumph for geology.

The preparatory hinged subsidence that we have met with in the history of the Caledonian Chain, in southern Scotland and again in Canada, reappears in the Hercynian record of western Europe. Broadly speaking, the Devonian of the Hercynian Foreland is continental (Old Red Sandstone), while that of the Hercynian Mountains is marine. Two main regions can be distinguished in the foreland, an eastern and a western. In the eastern, Lower Devonian is generally absent, while Middle and Upper Devonian are locally developed—in Belgium and the Baltic, but not in Orcadia, the upper division of the Middle Devonian is frankly marine. In the western region of the foreland, which includes England, Ireland and the south and west of Scotland, Lower and Upper Devonian are widely represented, in both cases as Old Red Sandstone, while Middle Devonian is unknown. The Devonian of the mountain land is fairly complete and predominantly marine, both in the east and the west; and it seems to have derived much detrital material from the north. Evidently this marine Devonian gathered on a tectonic slope that, descending southwards to the site of the future mountains, was constantly renewed by subsidence. The contrast between the foreland and the mountain region is particularly striking along the Franco-Belgian front of the chain. It has been exaggerated, as is so often the case, by overthrusting of regions previously separate; but even so the pre-thrusting contrast must have been thoroughly noteworthy. The Lower Devonian and the lower part of the Middle Devonian of the thrust region sometimes total 17,000 feet, while both divisions are absent in the over-ridden foreland to the north. The line at which this great mass of sediment fails is known as the Condroz Crest, and was familiar to Cornet and Briart when they wrote their cl ssic paper of 1877. To-day its course has been followed for 200 miles along the strike. I prefer to speak of it, when concerned with its pre-thrust character, as the Condroz Slope.

During Lower Carboniferous times, marine transgression submerged the Hercynian Foreland far and wide. A northern continent persisted, but its waste was retained along a deltaic belt that stretched through southern Scotland and northern Ireland. Accordingly, clear shallow

waters covered much of the foreland, for instance the greater part of Belgium, England and Ireland, where it encouraged the growth of Carboniferous Limestone. At the same time, the interior Hercynian zone, lying to the south, showed signs of mountain development, and uplifted portions furnished sand and mud to the contiguous sea. The contrast of the limestone facies of the foreland and the mud facies of the mountain belt is very reminiscent of what one has already described in connection with the Ordovician rocks of Canada. It is almost certain that the northward travel of the Hercynian mud was checked by a successor of the Condroz Slope leading down from the shallow waters of the submerged foreland to the foredeep of the growing chain.

Without attempting to sketch this history even in outline, let us pass on to Millstone Grit times, when a slackening in the general subsidence of the foreland allowed deltas from the persistent northern continent to join with others from the growing southern mountains. They met upon the site of the erstwhile Carboniferous Limestone Sea and thereafter placed Scotland in frequent communication with contemporary land regions in France and Germany. Just at this critical time, as Kidston and Traquair have shown, the land flora and estuarine fish fauna of Scotland underwent a remarkably sudden alteration; whereas the fauna of the open sea showed no corresponding change. The new flora, that all at once appeared in Scotland, is one that has been demonstrated by Potonié and others to have arisen in a normal gradual fashion on the deltas fronting the nascent Hercynian Mountains; and I attribute its abrupt introduction into Scotland to migration across the confluent southern and northern deltas of the Millstone Grit. The contemporaneous renovation of the estuarine fish fauna of Scotland can also be explained by the meeting of the deltas, since this event made Scottish rivers tributary to the general drainage system of western Europe. Hitherto these rivers had enjoyed biological isolation through emptying directly into the Carboniferous Limestone Sea. Henceforward their doors stood open to migration from the South.

There is another aspect of the deltaic apron of the Hercynian Mountains which used to appeal insistently to the imagination of Marcel Bertrand. This deltaic accumulation gathered in the frontal depression of the growing Hercynian Chain, and to-day it furnishes the greatest belt of coalfields in the whole of Europe. We know it in Upper Silesia and again in the Ruhr, Belgium, North-east France, Dover, Somerset, and South Wales. It is also represented in Ireland, but, as everyone knows, widespread denudation of Coal Measures is one of the admitted injustices that have been dealt out to our sister island.

Let us now turn to a very interesting feature of tectonics, of which there are two independent illustrations along the course of the Hercynian Mountains of western Europe: I refer to the crossing of mountain chains. In Upper Silesia the front of the Hercynian Chain emerges from beneath the Carpathians, while in the British Isles it obliterates for the time being the south-westward continuation of the Caledonian Chain.

Where the Carpathians and Alps have trespassed upon the domain of the Hercynian Mountains the latter had already been buried beneath an unconformable cover of Mesozoic and Tertiary marine sediments. This

relation is particularly clear in certain anticlinal re-exposures of the old mountains furnished by the Alpine massifs of the Aar and Mt. Blanc. Where the Hercynian front crosses the Caledonian Chain in Ireland the new mountains, at the present level of denudation, consist of Devonian and Carboniferous sediments; and the old mountains can only be seen to the north of them, uncovered by denudation along gentle anticlines developed in the foreland. In South Wales the crossing of the Caledonian Chain by the Hercynian does not proceed very far, for the strike of the older structures veers round into approximate parallelism with that of the modern chain at the line of mutual contact. It is not known whether this curvature is original or superinduced.

We may recall that the crossing of the two Palæozoic mountain chains of south-west Britain is one of the topics dealt with by De la Beche in 1846, in the first volume of memoirs published by our Geological Survey. 'This,' says Suess in his *Antlitz der Erde*, 'I cannot mention without an expression of deep gratitude to the author, now long since dead, since it exercised many years ago a decisive influence on my own views as to the structure of great mountain ranges.' If I were to continue the quotation it would lead on to the subject of granite intrusions in relation to folded mountains—but space absolutely forbids touching upon this side of the subject.

For the last time let us take boat across the Atlantic, there to visit the American representative of the Hercynian System. We know exactly where to go. From New York southwards, the north-west front of the Appalachian complex consists of folded and often overthrust Palæozoic sediments that extend upwards into Coal Measures. This belt it was that gave the brothers Rogers material for their ever-famous address delivered in 1842 before the American Association of Geologists. We need only recall how the two brothers demonstrated to a spell-bound audience the asymmetry, isoclinal packing, steep thrusts and general travel of the Appalachians; and how their work was immediately recognised as of international importance.

It has been said above that Coal Measures are affected by the folding of the portion of the Appalachians now under consideration. The last great movement seems to have been in the early Permian. Accordingly Marcel Bertrand, in 1887, placed this frontal Pennsylvanian belt of the Appalachian Complex in his Hercynian System.

The most interesting peculiarity of the Hercynian System in America is its penetration to Laurentia, to the north-west foreland of the Caledonian System. The crossing of the chains, begun in the British Isles, is completed in New England. The actual front of the Hercynian Chain cannot be mapped with precision in the American part of the zone of crossing, because the critical district has been largely denuded of its Carboniferous rocks. At the same time important Carboniferous outliers do occur in the southern States of New England and are strongly folded; whereas, it will be remembered, the Carboniferous spreads of the maritime provinces of Canada are tolerably undisturbed. The best known of the New England outcrops crosses Rhode Island, and its prevailing rocks are conglomerate, arkose and slate. There are also a few beds of graphitic coal, the Upper

Carboniferous age of which is shown by associated plant remains. Though folded, cleaved and cut by granite and pegmatite, the Rhode Island Carboniferous agrees with that of Canada in being unconformable to the Caledonian disturbances.

Where at last the Hercynian Mountain front steps clear of its Caledonian predecessor, one encounters a sedimentary superposition of facies that is quite unknown in Europe. In Pennsylvania there is an immense concordant succession from Cambrian to Carboniferous. In the cores of anticlines we find our Durness (Beekmantown) Limestone, because we stand on the north-west foreland of the Caledonian Chain. In the hearts of synclines we discover Upper Carboniferous Coal Measures (Pennsylvanian) derived from the waste of the growing Hercynian Mountains, and we follow Bertrand in our thoughts to South Wales, the Ruhr and Upper Silesia.

The study that we have made of mountain chains with their folds and their thrusts, which individually may be of the order of 100 miles, involves a recognition of some type of continental drift. Of late years Wegener has developed this idea on a particularly grand scale. He has accounted for many recognised correspondences in the geology of the two sides of the Atlantic by supposing that the ocean has flowed in between the Old World and the New, as the two continental masses, with geological slowness, drifted asunder. One cannot help feeling that Wegener may perhaps be telling us the truth. The available evidence is crude and ambiguous; but it is certainly startling to be confronted on the coasts of Britain and America with what read like complementary renderings of a single theme: the crossing of Caledonian Mountains by Hercynian.

THE ORIGIN AND EVOLUTION OF LARVAL FORMS.

ADDRESS BY

PROF. WALTER GARSTANG, M.A., D.Sc.,

PRESIDENT OF THE SECTION.

The transformations, or metamorphoses, of animals have always provided one of the most fascinating chapters of Descriptive Zoology. Their significance in relation to the doctrine of Evolution was a subject of animated debate by previous generations of zoologists, and figured largely in several Presidential Addresses to Section D, notably in those of the late Prof. Milnes Marshall, in relation to the theory of Recapitulation, at the Leeds Meeting in 1890, and of the late Prof. Miall, from the standpoint of Adaptation, at the Toronto Meeting in 1897. The conclusions arrived at by these two distinguished predecessors of mine were by no means concordant, and I hope I am not wrong in thinking the time ripe for reopening the subject. I propose, however, to take it from a third standpoint, distinct from theirs, yet related, which I may broadly define as the part played by larval forms in the course of evolution.

If we take any large class of marine Invertebrates the members of which can be seen to have made substantial progress along one or more lines of descent, a comparison of their larval forms shows that on the whole a larval evolution has taken place more or less parallel to that of the adult evolution, but subject to conspicuous deviations. Primitive types of larvæ are limited to the lower or more primitive sections of the class, and secondary larval characters become more and more pronounced in the higher and more recent members. In this general statement I am thinking of classes like Mollusca and Crustacea, in which the metamorphosis is gradual and continuous, and is not subject to sudden and radical changes of plan, such as are exhibited for example by Echinoderms and Polyzoa.

In Mollusca the primitive type of larva is obviously a Trochosphere, closely resembling that of Annelids in its pear-shaped body, præoral ciliated ring or prototroch, apical tuft, and absence of special Molluscan features such as shell and foot. It is found in each of the main sub-classes of Mollusca, except the Cephalopoda, viz. in *Chiton* (Amphineura), *Patella* and *Acmæa* (Gastropoda), *Dentalium* (Scaphopoda), and *Nucula* and *Yoldia* (Lamellibranchia or Bivalvia). All these are genera which, either in Mollusca as a whole, or in their respective sub-classes, retain a distinct preponderance of archaic characters—*Patella* and *Acmæa* belonging to the lowest section of Gastropoda (Zygobranchia, in spite of loss of the original

gills !), *Nucula* and *Yoldia* to the lowest section of Bivalvia (Protobranchia). But in the course of their career as free larvæ, these Molluscan trochospheres all acquire new and divergent features: the trochosphere of *Chiton* lengthens out and develops a dorsal series of cuticular, partly calcified, plates; that of the Limpet acquires a shell which is successively plate-like, cap-like, and nautiloid, its body undergoes the Gastropod torsion, and it then develops an operculum; the *Dentalium* trochosphere develops a pair of mantle-folds and a saddle-shaped shell, which becomes tubular by ventral concrescence of its edges; the larval *Yoldia* acquires a hinged bivalved shell, and both it, *Dentalium*, and *Patella*, but not *Chiton*, develop a foot.

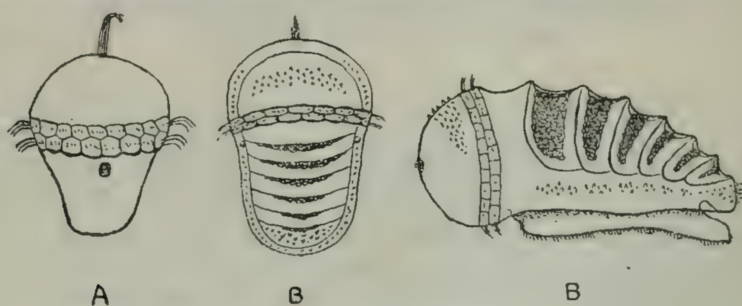


FIG. 1.—Larvæ of Chiton.
A, *C. marginatus*; B, *C. polii*.

It is readily seen that almost all these characters which the trochospheres acquire during their pelagic free-swimming career are in the direct line towards their respective adult characters. As soon as the rudiments of the shell have made their appearance, the larva of *Nucula* is definitely a Bivalve, that of *Dentalium* a præ-Solenoconch, that of *Patella* a Univalve, and that of *Chiton* Polyplacophorous. The secondary characters which appear are essentially adult characters in the making. They have mostly no relation to a pelagic career (*e.g.* the shell-plates of a *Chiton* larva), and may even be an encumbrance—witness the useless digging foot of the *Dentalium* larva—yet they appear. They can also be no heirlooms from pelagic ancestors, since shell and foot speak unequivocally of the ground—the archi-Mollusk was a benthic, not a pelagic animal. These secondary larval characters then are mainly anticipations of adult characters.

But they are not entirely of this nature, for among the examples mentioned the larva of the Limpet develops an operculum which is not present in the adult stage. The early trochospheres of *Dentalium* and *Yoldia* also show features which are both absent in the larva of *Chiton* and have no direct relation to their adult characters. Let us examine these cases a little more closely.

The trochosphere of *Chiton* has a simple prototroch consisting of two parallel rows of cells. As its body elongates the rudiments of six shell-plates arise behind the prototroch, apparently in metameric order from before backwards. During the pelagic career of the larva these plates remain cuticular and uncalcified; but, as growth proceeds and weight increases, the larva swims less and less freely, and takes to gliding along

the bottom by means of its pedal cilia. Calcification of the plates then sets in, again in order from before backwards. Simultaneously the creeping sole becomes enlarged by the development of muscles, and these effect attachment above to the developing plates. A cephalic plate in front of the prototroch, and an anal plate behind, are added, thereby completing the typical eight. The prototroch is then absorbed, and the adult life begins. The larval history is thus very similar to that of a simple Polychæte, although segments, in the strict sense of the term, are absent. As in Polychætes, also, the adult characters are not completed until the creature has descended to the bottom.

In the case of *Dentalium*[1] the trochosphere starts with a much more powerful prototroch of three rows of ciliated cells, and goes much further than that of *Chiton* in its development of adult characters during its free-swimming career, for it not only establishes the complete form of its tubular shell—which is much more elaborate than that of *Chiton*—but also develops its characteristic digging foot. There is plainly an adaptive connection between these two features: development of the additional adult characters has been conditioned by the greater ability of the larva

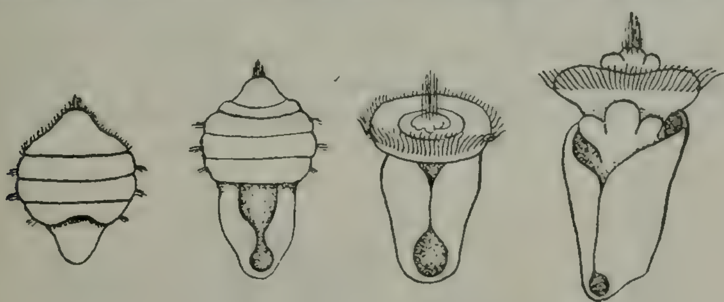


FIG. 2.—Larvæ of Dentalium.

to carry them. The ciliated prototroch is actually extended over part of the surface of the larval body by means of an internal duplicature of the skin behind it, the locomotive girdle projecting freely over the front of the body, like a collar over a coat.

This adaptive modification is carried to an even greater extent in the Protobranch Bivalves *Nucula* and *Yoldia*.[2] The collar becomes a great ciliated cloak or overall, and the duplicature is so deep and precocious that the whole post-trochal region is developed under cover of its five rows of ciliated cells, the middle three of which bear powerful flagella. At the end of the larval period a diminutive adult, fully formed, is deposited on the bottom by disruption of the prototrochal envelope or 'test.' Quick-change artistes are obviously not limited to the human species.

Embryologists are familiar with many other illustrations of this kind of development, *e.g.* the North Sea *Polygordius*, *Sipunculus*. It shows by easy steps how the more dramatic metamorphosis of *Pilidium* into a

[1] *Dentalium*, Kowalevsky, *Ann. Mus. Hist. Nat., Marseille*, I, 1883. According to the earlier account by Lacaze-Duthiers, the young trochosphere has no less than seven ciliated girdles, four of which give rise to the prototroch by a process of concentration, but their relation to the rows of cells was not described (*Ann. Sci. Nat.* (4) VII, 1857).

[2] *Nucula* and *Yoldia*, Drew, *Q.J. Micr. Sci.*, XLIV, 1901.

Nemertine may have arisen. However, without ranging further afield, these few examples may perhaps suffice to illustrate several important propositions:

(1) the larva has a double task to perform, viz. to distribute the species and to grow up into the adult;

(2) of these tasks the first is essential, and the second subsidiary—to be undertaken only so far as the larval resources permit;

(3) the performance of the two tasks together requires the maintenance of an equilibrium between the locomotive efficiency of the larva and the adult weight to be carried;

(4) the locomotive adaptation of the larva may proceed on new lines, paying no respect to phylogeny, and culminating in some kind of metamorphosis;

(5) the modification of the larva in this way need not affect the organisation of the adult, since the casting of the most hypertrophied of ciliated girdles involves only slight processes of subsequent repair.

When we pass from the more primitive and ancient groups of Mollusca to the more modern ones, the larva no longer hatches as a simple trochosphere, but is provided with a shell and foot from the first, and the simple girdle of cilia which constituted the prototroch is replaced by a much more powerful organ, the *velum*. This applies to all except the lowest members of the Azygobranch Gastropoda and to all Filibranch

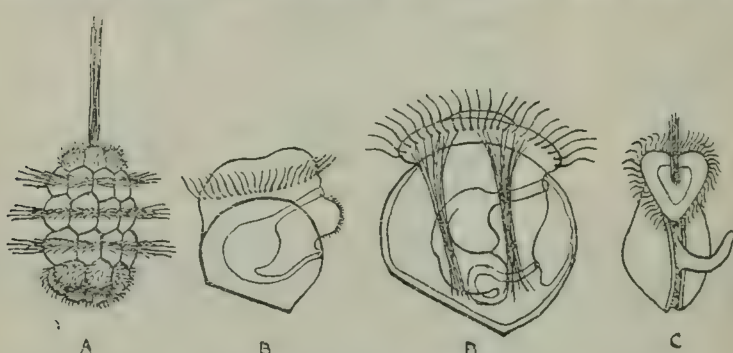


Fig. 3.—Larvæ of Bivalves.
A, *Yoldia* (*Protobranch*); B, *Ostrea*, and C, *Dreissensia* (*Eulamellibranchs*).

and Eulamellibranch Bivalves. The velum is only a special development of the prototroch, but by being stretched out at the edge of an extended disk or bi- or tri-lobed frill, the locomotive cilia of the girdle are greatly multiplied in number and power. The larva is the familiar Veliger, though it would be well to restrict this term to the Gastropod larva, and to distinguish the Bivalved form of it by a separate name, *e.g.* Rotiger, from the wheel-like form of its ciliated disk. Both the ciliated arms of the Veliger and the disk of the Rotiger can be protruded freely from the shell and as easily and completely withdrawn inside it.

There are of course many Gastropods and Bivalves in which, even under marine conditions, the free-swimming larval stage has been secondarily reduced in association with a marsupial or incubatory mode of development. Under these conditions the velum or ciliated disk never

attains its full size and is often arrested in a very vestigial condition. Finally, the pelagic stage may be suppressed altogether, and the Whelk emerges from the confinement of its brood-chamber as a diminutive adult, ready at once to pursue its definitive career.

The absence of any larval stage throughout the whole class of Cephalopoda is doubtless due to the locomotive agility of the adult which renders a distributive larval phase unnecessary. Although this explanation applies to few other cases of suppression, the fact seems from one standpoint to furnish the climax of the evolutional sequence we have been considering. For the larval phase, like the seed of a plant, is essentially distributive, and in the evolution of Mollusca we have to some extent seen it shift along the steps of the life-history from a very early, simply organised, shell-less stage, the Trochosphere, to an intermediate shell-bearing stage, from this to the highly adapted Veliger or Rotiger, and finally (if we may here include the Cephalopod and the Whelk) to the adult stage itself, the lower stages of development having been successively relegated to the embryonic period. Broadly speaking, this sequence corresponds with an increase in the yolkiness of the eggs, a very simple and widely distributed means of postponing the hatching period to a more advanced stage of development.

It is probably not without significance that this progressive shift corresponds with a time-sequence observable in the order of appearance of the groups concerned, the groups with free Trochospheres, viz. Zygobranch Gastropods and Protobranch Bivalves dating from the Lower or Middle Cambrian, while the groups with Veliger and Rotiger larvæ, the Pectinibranchs, Opisthobranchs, and Eulamellibranchs, appear to be unknown before the late Silurian. A curious exception, urgently calling for further investigation, is the alleged occurrence of Capulids in the Lower Cambrian.

Although, with fuller knowledge of the facts and of the bionomical conditions, it may be possible to explain the cases of reduction or obliteration of the larval stage in terms of adaptation, it seems more probable that there has been a secular change tending to depreciate the value of dispersal as the seas became stocked with an increasing number and variety of specialised inhabitants. When the adults have become highly adapted to the conditions of a particular kind of terrain (*e.g.* rock-life) a prolonged larval life would be of doubtful advantage which regularly carried a large percentage of the larvæ away from the rock zone altogether and landed them in an area of sand and mud.

On the other hand we cannot overlook Prof. Tattersall's *Littorina*,[1] which, not content with all the conventional larval stages, has started a new distributional device of its own by setting adrift the egg-case as well, remarkably adapted to that end.

It is with larval origins, however, not suppressions, that I am now concerned. To some zoologists this question does not arise, or at least presents no serious difficulties. With them larval stages represent foregone ancestors, and all they have to do is to account for discrepancies. As the chain of adult ancestors is drawn out, at each new evolutional

[1] *Littorina*, Tattersall, *Fisheries, Ireland, Sci. Invest.*, 1920, I.

advance the former adult is succeeded by a new one, and slips back into the ontogeny as a developmental stage. Let me briefly state why I am unable any longer to accept this theory. Firstly, it assumes that new steps in evolution are first manifested at the end of the ontogeny, *i.e.* in the ordinary course of adult life. I can find little or no evidence which supports this proposition, and an overwhelming mass of evidence which points against it. An example or two in Mollusca will be brought before you for consideration. Yet this assumption has even been used to support the theory of the inheritance of functional modifications acquired during the active life. Secondly, it is inconsistent with the actual course of development, which often preserves ancestral modes of development of individual organs, but as often as not introduces different organs at periods independent of any probable phyletic time-scale. The totality of an ontogenetic stage is thus normally different from the *tout ensemble* of any ancestor. Thirdly, it ignores what I regard as the chief outcome of modern Genetics. When this subject was last discussed in Section D, Mendel's principles had not been heard of, and Galton's Law of Ancestral Inheritance was the only generalisation in the field. There was nothing then to prevent us from assuming, and much to persuade us, that somehow or other the successive stages of growth were the expression of successive inheritances. To-day, on the other hand, such a phrase seems an anachronism. I feel bound to assume that development is the expression of a single inheritance. I take it that, whatever I may think as to the resemblance between this ontogenetic stage and that extinct ancestor, I may not assume any inheritance of the ancestral stage itself. My boy may be like his maternal great-grandfather and his sister like her paternal grandmother, but, as the phylogeny has been the same, the ancestral stages as such have obviously not been inherited ; and we now know why, or rather how, that comes about.

Viewing development then as the sequential expression of a single inheritance, Science confirms Wordsworth's observation of more than a century ago (1802) that

'The Child is father of the Man,'

and, subject always to the influence of environing conditions, our stages of development are 'bound each to each' by a necessitarian chain of progressive differentiations, each stage depending on its predecessor and determining its successor. The bearings of this doctrine on the problem before us do not appear as yet to have been fully appreciated, but squarely faced, they present issues which are of fundamental importance.

We have seen in the life-histories of *Dentalium* and *Yoldia* that a particular larval organ, the prototroch, can undergo considerable adaptive changes with great advantage to the race, and after serving its purpose can be absorbed, if small, or cast aside, if large, without leaving even a scar. You will note that the unity of the inheritance, and the necessitarian sequence, are not broken by this phenomenon. The prototroch is not a preliminary stage in the formation of any adult organ. If you regard the adult as the final complex resulting from a number of differentiating cell-lineages, the prototroch is only a little subsidiary twig near the base, on

which nothing else depends: it can be pruned off without injury to the rest of the series.

But we have also seen that the cell-lineages leading to certain adult organs may differentiate so quickly as to make the rudiments of these organs manifest in the trochosphere of which originally they did not form a part. What will happen if these partly differentiated rudiments should be capable of useful modification subservient to larval as distinct from adult ends? They will, *ex hypothesi*, be subject to the unity of the inheritance, and if the modification be irreversible, *i.e.* incapable of subsequent rectification, the adult form of the same organ will inevitably be affected. Thus some modifications of adult characters may be the result of larval mutations. Is there any evidence that such is ever the case? I believe such evidences are widespread, and that it is only the dominance of an erroneous hypothesis which has prevented us from recognising them before. Let me submit one or two examples in Mollusca for your consideration.

The systematic study of Mollusca has resulted, like that of other groups, in the production of a classification based on the principles of 'adult seriation.' Groups and sub-groups are defined ostensibly by their possession of certain combinations of positive characters; but the real basis is the occurrence of gaps, some large and deep, others slight, in the series of adults available for examination. As knowledge increases, these gaps are often reduced or filled up, and the positive characters defining the groups are then altered accordingly. But some gaps in the seriation remain obdurate: the more we know the sharper they become.

The main lines of Molluscan classification have long reached a stable condition: the gaps between the main sub-classes have undergone no reduction in the time of any of us here, in spite of an immense outpouring of new species and genera, trimmings and rearrangements of families and orders, recent and fossil, and in spite of a considerable increase in our knowledge of their comparative anatomy and embryology. I take the following scheme from Prof. Naef's recent and admirable revision[1] of the Morphology of the group (1926), changing it only by omitting a problematic group of ancient cone-shells (*Hyolithes*, *Conularia*, &c.), usually classed as Pteropoda, but which Prof. Naef raises to the rank of an order and terms Odontomorpha, apparently to suggest a relationship with *Dentalium*. In brackets I have added certain synonyms which may be more familiar than the primary terms actually adopted.

MOLLUSCA.

(*Sub-classes and Orders*)	(*Examples*)
I. AMPHINEURA	
1. PLACOPHORA	e.g. *Chiton*
2. SOLENOGASTRA	e.g. *Neomenia*
II. CONCHIFERA	
1. CEPHALOPODA	e.g. *Nautilus*
2. HETERONEURA (=Prorhipidoglossomorpha)	
i. GASTROPODA	e.g. *Patella*
ii. SCAPHOPODA (=Solenoconcha)	e.g. *Dentalium*
iii. BIVALVIA (=Lamellibranchia)	e.g. *Nucula*

[1] Spengel's *Ergebnisse u. Fortschritte*, III, 1913, and VI,2, 1926.

The gap between Amphineura and Conchifera is absolute: the shell in the former consists of a series of plates (or spicules), in the latter of a single plate (calcified from two lateral centres in Bivalvia). No Amphineuran, living or fossil, approaches the Conchifera by showing an enlargement of one of its plates as the possible predecessor of a single shell, and no Conchiferan, living or fossil, approaches the Amphineura by showing any signs of a duplication or segmentation of its shell into metameric plates.

Similarly in Conchifera, whether the Nautiloid or the conical shell be regarded as primitive, no Cephalopod shows any signs of a lateral torsion approaching the Gastropod twist, and no Gastropod exists with paired gills, auricles and kidneys without also displaying a complete torsion of its mantle-cavity and shell through 180° from back to front. The same peculiarity marks off the Gastropoda absolutely from the Scaphopoda and Bivalvia, although in other respects the morphological agreement between these three orders is extensive and detailed and their relationship must be exceedingly close.

Now let us turn to the larval history of a primitive Gastropod, say *Patella*[5] or *Trochus*,[6] and see how this torsion is accomplished. The

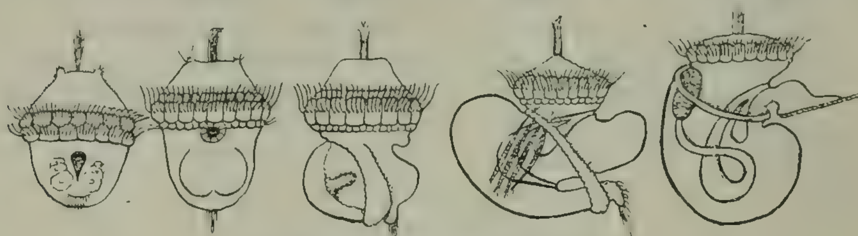


FIG. 4.—Larval Stages of Patella.

trochosphere develops a cap-like shell upon its back, and swims about with it. As the mantle grows more rapidly behind than in front, the additions to the shell are also more extensive behind than in front, so that, relatively to the newer and broader part, the original ' cap ' is slowly and steadily pushed upwards and forwards as the apex of a commencing coil. This coil of the larval shell is not quite median in existing forms, but there is reason to believe that it was so in the earliest Gastropods, as shown by the symmetry of the shells in practically all Gastropods known from Cambrian and Ordovician strata (e.g. *Cyrtolites, Sinuites, Salpingostoma, Bellerophon*). Thus the larval shell grows like that of the Pearly *Nautilus* and is at first orientated in the same way: the apex of its coil is directed upwards and forwards over the larval head (exogastric), and a gill-chamber is developed beneath it behind, corresponding to that of *Chiton* and *Nautilus*. At this stage the foot projects freely but carries no operculum; and it is easy to see from the arrangement of parts that an operculum on the foot would be meaningless. For the head is separated from the gill-chamber behind by the whole length of the foot, and, when the body

[5] *Patella*, Patten, *Wien Arbeiten*, VI, 1886; *Acmæa*, Boutan, *Arch. Zool. Exp.*, (3) VII, 1899.

[6] *Trochus*, Robert, *Arch. Zool. Exp.*, (3) X, 1903; and *Zoologie Descriptive*, II, 1900, fig. 508.

contracts, it is the foot, not the head, which can safely withdraw into it, leaving the head, the most vital part of the body, exposed to attack. This vulnerability of the head in the Nautiloid stage of a Veliger is obviously a defect, but it is not long in being remedied. Head and foot as a whole rotate round through 180° until their relations to the mantle-cavity are exactly reversed. According to Boutan, the whole process of torsion is accomplished in *Acmœa* in two or three minutes, so that, as Prof. Naef has pointed out, it is difficult to believe that the change is accomplished by ordinary processes of growth alone. A certain amount of true twisting by muscular contractions would seem to be involved. In *Trochus* (Robert, 1903), the first of all Azygobranchs, the torsion requires six to eight hours. In both forms the shell has already begun its Nautiloid exogastric coil before there is any sign of torsion. In still less primitive forms (e.g. *Paludina*), as Miss Drummond[7] was one of the first to show, the torsion takes longer than in *Trochus*, and starts at a much earlier embryonic stage, before the shell has begun to coil. It is thus probable, as Prof. Naef maintains, that the slow achievement of the torsion by growth-processes spread over a considerable portion of the ontogeny is a secondary modification.

The immediate effect of the change, when completed, is to bring the gill-chamber to the front of the larval body, thus enabling the head, with its all-important velum, to be safely withdrawn into it at the first onset of danger. The foot lastly develops an operculum on its hinder surface, which closes the entrance on contraction.

In the Limpet this rotation is effected during the free larval life, probably as quickly as in *Acmœa*, its next of kin; but in *Trochus* and all subsequent types of Gastropods (Azygobranchia) it takes place in the embryonic phase, so that the Veliger has already undergone torsion before hatching. There can be no two opinions as to the great advance in efficiency shown by the new type of larva as compared with the old. Unfortunately information about the Nautiloid larva of the Limpet and its post-torsional successor is still limited to Patten's observations on specimens reared from artificial impregnations, and neither Patten nor Boutan say much as to the habits of the larvæ. It is also difficult to say whether in its retention of a simple prototroch the larva of the Limpet is primitive or secondarily simplified, but the curious changes and variations which have been described in the structure of its prototroch point rather strongly towards the latter conclusion. The larva of *Acmœa* shows signs of even greater reduction of its prototroch, since the ciliary girdle, though composed of two rows of cells, carries only one row of flagella (Boutan). In *Fissurella*[8] there can be little doubt on this point, for the larva *creeps* out of its egg-shell, instead of swimming, and settles down with the least possible delay to its sedentary rock-life, at once proceeding to absorb the prototroch which it has never used in the open sea, and casting the operculum which it has never used at all. The development of *Pleurotomaria* may some day

[7] *Paludina*, Drummond, *Q.J. Micr. Sci.*, XLVI, 1892; Boutan, *l.c.*, 1899; Naef, 1913, p. 102.

[8] *Fissurella*, Boutan, *Arch. Zool. Exp.*, (2) III, 1886.

reveal the original larval type of a less specialised Zygobranchiate Gastropod.

But the fully developed post-torsional Veliger of an ordinary Azygobranch is thoroughly adapted to an active pelagic career. Its prototroch having now grown out into a pair of velar lobes, the larva no longer rotates like a trochosphere, but directs its movements up, down, or straight ahead on a perfectly even keel. Its velum is so powerful that it can easily sustain the added weight of its partly calcified shell. When suddenly disturbed it reacts in characteristic fashion: its head and velar lobes are immediately withdrawn into the now adjacent gill-cavity, the foot smartly follows suit, and the door is automatically closed by its horny operculum. Owing to its weight the larva falls vertically downwards in the water the moment it stops swimming. As an obscure præ-Georgian poet has somewhere described it:—

'The Veliger's a lively tar, the liveliest afloat;
A whirling wheel on either side propels his little boat;
But when the danger signal warns his bustling submarine,
He stops the engine, shuts the port, and drops below unseen.'

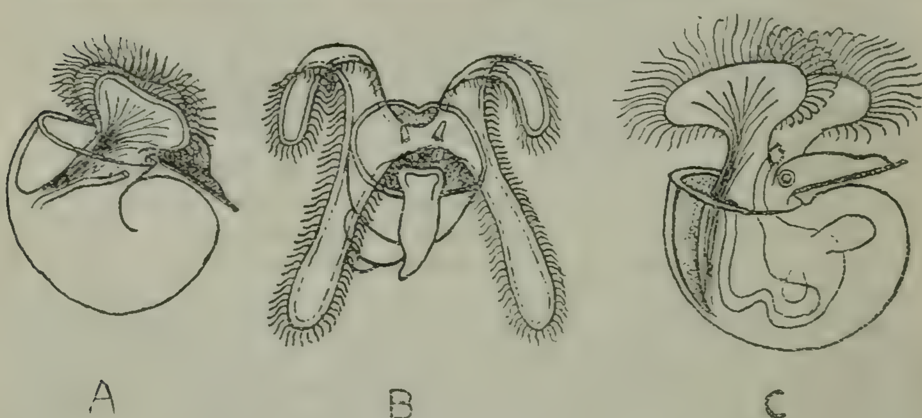


Fig. 5.—Veligers of Azygobranchs.
A, *Nassa*; B, *Dolium*; C, *Opisthobranch*.

Now if I have succeeded in my description of the principal points, I think you will agree that whatever significance may be attached to the twist of its body in an adult Gastropod, there is no doubt about its value to the larva. As to the origin of this torsion, all previous attempts to explain it have been based on the assumption that it arose during the adult life of some early type of Mollusk. I do not propose to go into all these theories, instructive as they are, since their divergences merely illustrate the difficulty of any solution on those lines. Like the asymmetry of *Amphioxus* and the one-sided preponderance of Echinoderms, the torsion has remained a standing puzzle. It has been hardly attempted to assign a utilitarian value to the initial and intermediate stages which must have been required to effect the change in a series of adult ancestors. I will deal later with the further point as to the failure of any of these intermediate links to persist.

In any case I venture to suggest that the torsion of Gastropods arose in the first place very much as you see it develop to-day, as a larval adaptation, in response to larval needs; and that it was perpetuated because, once accomplished, it was of immediate advantage both to larva and adult. It transformed the earlier Nautiloid type of larva into the much more effective Veliger; and the Veliger, settling down to resume the benthic life of its sire, found no serious obstacle to growth in the new arrangement. Lastly, the adult, whose head had previously had little or no protection, was now able to withdraw it on disturbance into complete safety. I assume that the ancestor had a muscular creeping foot, neither so simple as that of *Chiton*, nor so complex as that of a Cephalopod, but definitely suctorial, though capable of progression.

The only mutation required to start the torsion in the assumed ancestral præ-Gastropod larva was an asymmetry in the development of the retractor muscles, thus bending the head and foot round during contraction; but it remains for further investigation to show whether or not the rotation in *Patella* and *Acmæa* is actually determined in this way, as indicated by the rapidity of its accomplishment. The ideal muscular arrangements for bringing about complete rotation would consist of a right-sided cephalic retractor with posterior attachment and a left-sided pedal retractor with an attachment in front of the other, the two crossing one another more or less at right angles. Patten's figures show that these conditions are realised in the præ-torsional stage so far as the right side is concerned (see fig. 4, second figure from the right), but unfortunately leave us in the dark as to the arrangement of muscles on the left side. It is manifest, however, that, owing to the small size of the larval body, any muscular disparity between right and left sides in the direction indicated would conduce towards a reversal of the relations of head and foot to the mantle-cavity at every contraction, while fixation of the organs in the reversed position would be a simple matter at this stage of development, when the body-muscles are just beginning to be actively differentiated, and their connections have yet to be established. Thus, although the theory of a larval origin of the Gastropod torsion cannot be established on our present data, we can at least claim that rotation *may* have been accomplished in the way suggested, and that the ease and rapidity with which it could be achieved contrast favourably with the difficulties besetting any theory of progressive torsion through a long series of adult ancestors. In the larva the smallest twist would produce a favourable change.

In his own ingenious theory of 1913 Prof. Naef has suggested a novel way out of some of these difficulties. He regards the ancestor of Gastropods as a free-swimming Mollusk, not unlike a small *Nautilus* in appearance and habits, but with a more flexible ' neck ' or stalk connecting the anterior combination of head and foot (or *Kopffuss*) with the visceral or mantle sac behind; and he associated the origin of Gastropods with a change of habits from swimming to creeping. The Nautiloid position of the shell with the coil forwards and the aperture behind is regarded as convenient for swimming (Prof. Naef does not note that this is only true of *backward* swimming!), but is assumed to have been incompatible with creeping, owing to pressure of the coil on the animal's head and neck. A ' correction ' of these arrangements was therefore needed, which has

been achieved by the actual torsion. The greatest novelty of Prof. Naef's theory now comes in. He supposes that the earliest Gastropods and their immediate predecessors, owing to the flexibility of their 'necks,' were able to twist their shells round, from back to front, or *vice versa*, at will —as freely, he adds, as a bird can turn its head. On this theory the difficulty as to intermediate stages disappears. A snail that has undergone torsion has not acquired something entirely new: it has merely reversed what may be called the resting attitude of its shell. The power of twisting its neck was not entirely lost until the process of reversal was completed. By that time, however, the snail had given up swimming altogether, no longer needed the *Nautilus* poise, and had settled down to the monotony of a creeping life. As an intermediate stage it is suggested that the symmetrical shells of Cambrian snails (e.g. *Bellerophon*) may have rested sideways, *i.e.* with the spire over the left side of the body and the open end over the right—a position from which it would require, as it were, only half a pull on the left side to bring the shell back to the *Nautilus* position for swimming, or half a pull on the right side to bring the open end forwards into the position most suited to creeping.

For the rest I ought perhaps to add that Prof. Naef explicitly rejects the theory of the Veliger which I have adopted here, viz. that it is a Trochosphere transformed by the incorporation of Molluscan characters, and regards the Veliger as a 'phylogenetic reminiscence' of the pelagic ancestor of Gastropoda, which was adapted for swimming like a Pteropod by means of an expanded and bilobed foot.

You thus have before you two theories in explanation of the same facts, and the only tests by which you can judge between them are the degree to which they conform to well-established facts, and their consistency with the order of events revealed by a wider survey. As I have put before you a rival explanation, I may perhaps point out in what respects Prof. Naef's theory seems to me to be lacking in cogency: (1) We know that the morphological relations, both anatomical and embryological, of Gastropods to Scaphopods and Bivalves are much closer than to Cephalopods, and we are on sure ground when we conclude that the præ-torsional ancestor of Gastropods resembled primitive Scaphopods and Bivalves more closely than it resembled any Cephalopod. This is, in fact, what Prof. Naef's own classification means. By this test two of Prof. Naef's principal assumptions fall to the ground: the adult præ-torsional Gastropod did not possess a narrow flexible 'neck,' or the special muscles required by his theory, or a highly coiled Nautiloid shell. At the point when Gastropods diverged from Scaphopods, and Bivalves, the shell can have been little more than a flat plate. The difference between the two came in with the assumption of a lateral position of the gills in the Scaphopod-Bivalve line and a posterior position in the Gastropod line, thus leading to a preponderating lateral growth of mantle and shell in the former, and a dominating posterior growth in the latter. This entailed an anteriorly directed apex of the shell in præ-torsional Gastropods, as in *Nautilus*, though the resemblance must have been one of simple convergence, since the separation of the whole stock of Prorhipidoglossomorpha from that of Cephalopoda had taken place at an earlier stage, when the shell was presumably still flat. It is apparent from his

discussion and diagrams that the tubular shell and elongated body of *Dentalium* have exercised an undue influence upon Prof. Naef's mind as furnishing a kind of connecting link between Gastropods and Cephalopods. They are, of course, indubitably secondary features. Prof. Naef's comparison between the apical slit in the shell of *Dentalium* and the marginal slit of the lower Gastropods will be dealt with at a later stage. (2) Having concluded on these grounds that the common ancestor of Gastropods, Scaphopods and Bivalves possessed a flat shell and no narrow waist capable of rotation between *Kopffuss* and visceral dome, it is easy to see that the phyletic linkage of this group to still lower forms of Mollusca must be with forms of the Placophoran rather than the Cephalopod type. I do not mean that the Conchifera do not form a natural assemblage, but simply that the first Conchifera must have been essentially *Chiton*-like in organisation except for the simplicity of their shell: the conversion of the discoidal shell of the earliest Conchifera into cones, tubes, and spires has taken place independently in Cephalopods, Scaphopods, and Gastropods, in relation to very different habits of life.

If these considerations are well based, there can be no presumption in favour of a pelagic ancestry of Gastropods, and the attempt I have made to explain the evolution of the Veliger larva without regard to such 'phylogenetic reminiscences' can be submitted without anxiety as to objections on that account. The only pelagic feature of a Veliger is its velum, and that, as we have seen, comes down from a Trochosphere, not from a pelagic Mollusk. The bilobed origin of the foot in *Patella* and *Trochus* admits of various alternative explanations.

It will be noted that Prof. Naef's argument in support of the sudden and muscular character of the original process of torsion remains unaffected. He constructed his case from the observation of larval behaviour, but applied it to the behaviour of hypothetical primæval adults, which could not possibly have behaved like larvæ if they had existed. On the other hand, if you prolong backwards into the Cambrian the larval sequence which is demonstrable to-day, and project into it a continuation of the train of modifications in the mode of development of the torsion which we have also seen to be operating, step by step, and sub-order by sub-order, there appears to be neither speculation nor hypothesis in the conclusion that torsion in Gastropods arose as a larval mutation: the logic is that of simple mathematical extrapolation, or of projecting a curve the equation of which is known.

Of course I cannot tell whether you consider my proposition reasonable, or not, on the evidence I have put before you, and I have sought to base it entirely on positive grounds which are open to verification. Let me, however, now draw your attention to the secondary or corroborative evidence. At the outset of my discussion I remarked on the sharpness of the gap which separates Gastropoda from all other groups of Mollusca. The one thing, *i.e.* the only thing of importance, that distinguishes Gastropoda from other Conchifera is their torsion, and that is complete from the start. Torsion makes the Gastropod, and it appears in the systematic sequence as a true saltation. Now if torsion arose in the first instance by gradual modifications of adult form, each step fitted to some particular combination of external conditions or internal functionings,

surely somewhere over the wide earth we ought to have found a Zygobranchiate snail with its torsion incomplete. There are, I believe, 180 degrees in a half-circle. Allowing 10 degrees as a reasonable range for each successive stable position in a series of adult modifications, we have eighteen different positions in which some snail or other might reasonably be expected to have made a halt in the orthogenetic advance.

In the Opisthobranchiate Mollusca there is abundant evidence that an evolutional process of *detorsion* has actually occurred. Anus, gill, and kidney, at first in their mantle-chamber, have travelled back again along the right side of the body, reversing the original order of events. There can be no confusion between the stages of retreat and those of advance because all of these unwinding snails have come back without certain organs of the original left side with which they went forward. Every possible stage from complete torsion through partial to complete detorsion—far more than the eighteen grades which I assumed—is represented to-day by families, genera, and countless species—*Actæon*, *Bulla*, *Philine*, *Aplysia*, *Eolis*, *Doris*, &c., not to speak of the Pteropods derived from them. Their variety shows us what must have occurred on the forward march of the præ-Gastropods if it proceeded by comparable stages; and although many that went forward would certainly fall out in the long lapse of time owing to changed conditions, yet there must have been opportunities for adaptations capable of preserving the essentials of one or more of these eighteen advancing types. We know this from facts. In each minor group of primitive snails, possessing clear remains of the original bilateral symmetry of gills, auricles, and kidneys, there are genera which have come down to us unchanged from Silurian times at least, e.g. *Patella* and *Acmæa*, *Pleurotomaria*, *Turbo* and *Trochus*; and scores of other Zygobranchiate genera exist which only differ from their Cambrian ancestors in trifling details of shell sculpture. Yet not one of these snails falls short of complete torsion through 180°.

It seems impossible to avoid the conclusion that the gap in the adult succession between normal symmetrical Mollusca and Gastropoda is due to some cause other than natural extinction or the imperfection of the 'biological record' to be read in the existing fauna. The gap marks an evolutional saltation. The Gastropod accordingly is a 'sport,' and is the consequence of a sudden jump in the evolution of the Veliger larva in Cambrian, possibly earlier, times. With its visceral dome reversed this new larva settled down and grew to maturity, the general course of growth being unaffected by the change. When its growth finished, the first Gastropod had been created. How far the first Gastropod differed in other respects from its predecessor would require a long argument to tell, except as regards one character to be dealt with in a moment. There could be no trouble over its reproduction, since in *Chiton* and the Zygobranchs eggs and sperms are shed into the sea. The new characters were presumably dominant: the recessives, if any are now left, are apparently non-viable. Whether a gene was added, or dropped, I leave to geneticists.

At this stage I dare say the thought may be crossing the minds of some of you that snails always have been queer-looking things, with something abnormal about them, and that definitely to label them as 'sports' will not seriously disturb any cherished convictions. Even if the abnormality

first appeared in a Veliger, that is merely to say that one larva went wrong, whereas most larvæ behave properly. Let the Gastropod go into the same pen with Darwin's Niata cattle, and its veliger with the abnormal embryo that produced the La Plata race—what then? Stands not Scotland where it did?

You will note, however, that Gastropods form no inconsiderable section of Mollusca, and that Mollusca constitute one of the nine large phyla into which the animal kingdom is divided. A few years ago I brought a case very similar to this, but without any touch of abnormality about it, to the notice of the Linnean Society, and claimed that the carapace of Crustacea was also in the first instance a larval adaptation in some primitive Trilobite. If that case holds too, as I firmly believe, and as I hope before long to establish in full detail, the whole phylum of Crustacea must be added to Gastropoda and the Niata cattle. Last year, at Leeds, I put forward some new grounds, now published with fuller details, for the conclusion that Appendicularians are not primitive Tunicates, to be acknowledged by Ascidian tadpoles as their ancestors, but Doliolids gone astray in their development. The larval form in this case has ousted the adult from its supremacy in the life-history and has created a free-swimming pelagic creature out of originally sessile ancestors.

In short the Gastropod and its Veliger loom large in this address, not as ends in themselves, but as an additional example of a wide-ranging phenomenon. The man in the street scoffs at the idleness of the question 'Did the hen come first, or the egg?' He thinks it one of Nature's insoluble mysteries, but admits the priority of the egg when it hatches into a monster with two heads or three legs. In a sense I have looked around for a convenient monster, have found it in the snail, and now seek to show that 'the exception proves the rule.' I stick to snails because we are dealing with a problem which requires a certain amount of concentration, and one point assists another.

We left the ancestral Veliger creeping on its rock and growing up into the first Gastropod, and we are to ask if the new position of its visceral dome, twisted round through half a circle, was not attended by some inconveniences. Before the torsion the gill-chamber lay behind, as in *Chiton* and *Nautilus*. It was a more definite chamber than in *Chiton*, but not so big as in *Nautilus*, and its cavity opened downwards behind the foot, not forwards as in Cephalopods, because its walls were not specialised to propel the animal backwards through the water. This is where bionomics comes in to help morphology. When Prof. Naef treats the ancestor of Gastropods as a kind of *Nautilus*, he is putting the cart before the horse, or, more exactly, the specialised condition before the unspecialised, the higher before the lower. Before the mantle-cavity of *Nautilus* was used as a locomotive organ, it must have been what it still is in Gastropods, a simple shelter for the gills, and a passage for the products of anus, kidneys, and gonads. This curious combination of cloaca and respiratory chamber, easily explained by its evolution from the condition seen in *Chiton*, implies arrangements for maintaining a through circulation of water, as well as for preventing contamination of the respiratory water by waste products. In Cephalopods the respiratory current is maintained by muscular pulsations, in Gastropods by ciliated

tracts, and there can be no question as to which of these methods is primitive. Not only is the respiratory mechanism of *Nautilus* more advanced than that of any Gastropod, but *its use as a locomotive device is also secondary*, being but a further elaboration of the breathing movements. The inferences we drew from the shells of Mollusca are thus confirmed by a consideration of the gill-chambers. It is not *Nautilus* but *Chiton* that shows us most nearly the form of Gastropod (and indeed Conchiferan) ancestors. In *Chiton* the gill-chamber is hardly established as such: the groove between mantle and foot is open at all points, being merely a little deeper behind than in front. Water flows in at the sides, bathes the gills hanging from the roof, and escapes behind where the anus lies between the symmetrical pores of the kidneys, everywhere overhung by the projecting mantle-frill.

And now suddenly these excellent sanitary arrangements have been turned round from back to front through the efforts of a præ-Veliger to get its head into the hole before its foot (the Lamarckism may be excused!), and by the persistence of the larval adaptation. Before the torsion the gill-chamber opened freely behind; after the torsion the free exit of water and waste products was impeded by the snail's head and neck. There were two possible solutions of this dilemma: either the snail must die, and so wipe out the larval mutation altogether—in which event, had it happened, there would have been no order of Gastropoda to perplex the Zoological student—or a new exit must be provided. The latter alternative was followed. Every member of the most primitive section of Gastropods to-day, *i.e.* every snail which possesses paired gills and auricles (Zygobranchia), has in one form or another a slit or a hole piercing mantle and shell where these overhang the gill-chamber in front. It is not present in the larva; it does not appear until the larva has settled down to its permanent life on the bottom. It is an insignificant notch in the simpler cases, and yet it is to the development of this 'breathing hole' that the survival of the whole order of Gastropoda must be ascribed. Bearing in mind the direction of the ciliary currents in *Chiton*—in at the sides, and out at the middle—we must picture the young snail with these arrangements, but reversed now from back to front, and at the outset of its life on the bottom, possibly with one of Dr. Bidder's Torridonian tides swirling over it. Also we must recognise the effects of continuing growth and differentiation—increase of size and gill-surface, multiplication of muscles between shell above and foot-surface beneath, contractions of these muscles pulling the shell down on to the animal's neck, increasing metabolism and output from rectum and kidneys—all demanding increased ciliary activity, and greater outpouring of waste water beneath the middle point of mantle and shell. If I could start again as an Experimental Biologist I would greatly like to try the effect on a growing epithelium of a continued stream of deoxygenated water charged with a suitable quantity of metabolic waste. Would it or would it not inhibit growth at the point affected? In any case, whatever the chain of cause and effect, that is what happens now in the development of every young Zygobranch at the outset of its adult life. Beginning with the intact edge of the larval mantle and shell, the mantle grows less and less freely at the middle point where the waste water is poured out and grows freely everywhere else, with the resultant

formation of this so-called 'marginal slit,' which of course is also manifested by a corresponding gap in the shell. As growth proceeds the viscera behind occupy an increasing proportion of the space below the shell, and the gill-chamber itself shifts forwards, so that continual readjustment of slit to cavity is required. In *Emarginula* the mantle maintains the slit at its edge throughout life. As the mantle extends, the slit extends; but the intact part of the mantle behind also extends, and seals up with a secondary deposit the older parts of the slit in the shell. Thus arises a long seam in the shell, the so-called 'slit-band,' which marks the track along which the slit has travelled. In *Fissurella*, the Key-hole Limpet, a different arrangement prevails: as soon as a slit of sufficient size has been

FIG. 6.—Post-larval Development of Fissurella.

produced, the edges of the mantle meet in front of it and fuse, the mantle thus regaining its original integrity. The shell now goes on growing as intact as a Limpet's, leaving a hole near the summit which retains communication with the gill-cavity throughout life, and is enlarged from time to time by absorption. In *Haliotis* the mantle goes on splitting and closing throughout life, thus adding to the number of holes instead of enlarging the first one. The first and its successors are sealed up, one after the other, as the mantle-chamber grows forwards into new positions.

These various arrangements of slit and pores, with numerous intermediate conditions, are adaptive to minor differences of body-form and habits. In some the gills are equal and symmetrical, in others unequal and squeezed to one side; the body may be tall and pyramidal, or flat and broad, the shell accordingly conical or spiral, and carried above the foot or brought down to the substratum. In all, whether symmetrical or asymmetrical, the slit or series of holes lies in the morphological median line, between the two gills, and is associated with a persistence of the original bilateral arrangement of the inhalant respiratory currents. To its presence beyond all doubt the Zygobranchia owe the preservation of their original pair of gills in the reversed mantle-chamber. As soon as the right gill goes (Azygobranchia) the slit goes too, and a new current, oblique in direction, but simple instead of complex, is set up through the chamber, water entering in front on the left side, bathing the persistent (left) gill, then crossing to the right side to which the anus is diverted, alongside the persistent (right) kidney. Entrance and exit are each defined by special folds of the mantle-edge, which may be drawn out into

long spouts in front and behind. The evolutional changes in the gill-cavity are somewhat complicated morphologically, but physiologically can be summed up in a single word, sanitation. The various readjustments amount to a series of experiments in the more efficient separation between the respiratory and excretory arrangements, and finally result in the substitution of a simple system which cannot go wrong for one so intricately balanced that it will only work if its owner keeps perfectly still. It is no accident that Zygobranchism is associated with a sedentary rock-life, and that Azygobranchism is distinctive of the snails with versatile and wandering habits.

The true Limpets (Docoglossa) of course gained the same end by different means, sacrificing first one, then both gills in the mantle-chamber, and substituting for them an entirely new system of marginal folds outside the primitive gill-chamber altogether.

From this survey of the facts it seems to be a legitimate inference that the reversal of the mantle-chamber did in fact introduce some serious difficulties into the adult life of the first Gastropods. Retention of the complete ancestral organisation was rendered impossible except by an immediate modification of the mantle margin, and even this permitted no deviation from a very restricted mode of life. ‘Radiation’ into other environments requiring greater activity was inhibited by the delicacy of the respiratory adjustments, consequent on the partial blocking of the branchio-cloacal aperture. Had the torsion taken place by instalments in successive generations, some of the modifications which were subsequently introduced (with the Azygobranchia) would almost certainly have been accomplished *en route*, and would not have been deferred until the rotation was complete. The nature of the earliest post-torsional modifications thus corroborates the more direct evidence that torsion was, so to say, imposed upon the adult stage, and not primarily developed in its interest.

But the marginal slit has bearings on the general problem which are direct as well as corroborative, since it provides us with a test case of the origin of a typical adult character. We know from Boutan's account of the development of *Fissurella* that there is not a sign of the slit before the sedentary stage is entered upon, and his figures show that an area of shell is produced equal to that of the whole embryonic coil before the marginal slit begins. This area is a mere trifle compared with the ultimate size of the adult shell, but it is enough to show that the slit is a purely adult character and arises at the outset of the adult life.

Now the history of the slit is engraved upon the face of every Zygobranchiate shell, and the date of its commencement in the adult life is to be got by following the ‘slit-band’ to its source. In every Zygobranchiate living to-day the ‘slit-band’ begins, like the hole of *Fissurella*, near the apex of the shell in front of the larval coils. Moreover the inscription on the shell is so distinct, and the shell so durable, that it can be read on the shells of the earliest Cambrian and Silurian fossils. Here also in every case, even in the primæval *Bellerophon*, which retains perfect bilateral symmetry in its nautiloid coil, the slit-seam runs up from the margin of the shell nearly to the apex of the coil. There has accordingly been no change from first to last in the period at which the slit develops.

In the first Cambrian Gastropods it must have arisen as a marginal notch almost immediately after the beginning of the adult life, just as it develops

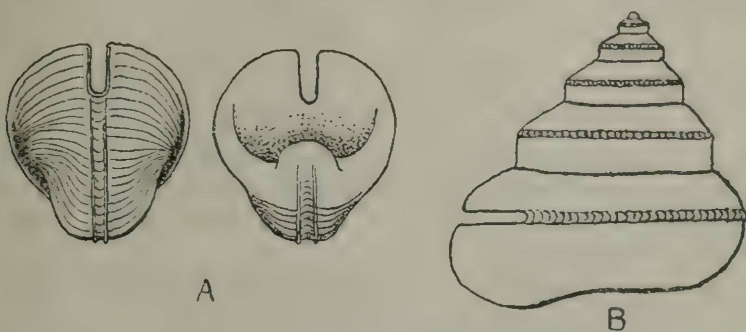


FIG. 7.—Shells of Adult Zygobranchs.
A, *Bellerophon* (*Cambrian*); B, *Pleurotomaria* (*Silurian onwards*).

now; while there is every indication that torsion took place, as it takes place now, during the embryonic or larval, and not the adult, stage.

Prof. Naef has indeed attempted to trace a homology between the apical hole of *Fissurella* and that of *Dentalium*, which, if it could be sustained, would make the slit a præ-torsional instead of a post-torsional modification. He even figures the slit as a feature of the shell before, as well as after, torsion in his diagrams of this process. There is of course a certain correspondence in the position of these two apertures or slits, since both are morphologically median and posterior. But whereas the hole in *Dentalium* is simply a remnant of the original gap between the paired mantle-flaps of the larva, that of *Fissurella* is formed post-torsionally at the extremity of a free median outgrowth of the mantle which has no representative in *Dentalium* or the Bivalves. Moreover, in Gastropods the slit is at right angles to the main mantle-edge: in those Scaphopods which possess a slit as well as a hole, this slit, like the hole itself, is merely a gap between the mantle-folds themselves. These differences are quite sufficient to distinguish the two holes as examples of simple convergence.

Having now put before you all the salient facts as to the history and function of this Zygobranchiate slit, I need scarcely point out to you how admirably these facts serve to disentangle the elements of truth and error which Haeckel so confused in his 'Biogenetic Law.' *Fissurella* has an apical hole which develops by fusion of the lips of a transitory marginal slit. *Emarginula* retains a marginal slit throughout life. It is a statement of simple fact to say in a general way, and with regard to this character, that *Fissurella* goes through an *Emarginula*-stage in its development. But does it follow that the *Emarginula*-stage of *Fissurella* represents an *adult* ancestral condition? On this evidence clearly not, for the adult ancestral condition, *ex hypothesi*, is that of *Emarginula* itself, and *Emarginula* when definitely adult possesses a long 'slit-band' which is completely lacking in *Fissurella*. Let us condense the facts of the two ontogenies symbolically and assume, as is not improbable, that one has been derived from the other. If this assumption is disputed the case for

adult recapitulation naturally falls with it. On the Haeckelian hypothesis the inheritance runs like this :—

Emarginula : Egg—Larva—Adult
↓ (with slit)
↓
Fissurella : Egg—Larva—Neanic stage—New Adult
(with slit) (with hole)

Fissurella is regarded as inheriting all that *Emarginula* has to give, and as then adding a new stage to the series. This differs from the previous adult stage, but is built up out of a Neanic stage, which is claimed to represent the previous adult.

But we have seen that the complete adult ancestral stage is not inherited : the whole of the post-Neanic ontogeny which includes a ‘ slit-band ’ is absent from the ontogeny of *Fissurella*. We must therefore distinguish like from unlike, and represent the two ontogenies differently :

Emarginula : Egg—Larva—Young Adult—Old Adult
↓ ↓ (with slit) (with slit-band)
Fissurella : Egg—Larva—Young Adult—Old Adult
(with slit) (with hole)

From this analysis it results, so far as this one particular character is concerned, that the ontogeny of *Fissurella* repeats the ontogeny of *Emarginula* up to the Neanic stage of the latter, but no further, and then deviates. There is thus no ‘ compression ’ of the whole adult stage of *Emarginula* into the Neanic stage of *Fissurella*. It is much the same with regard to all other characters, with this qualification, that the point at which divergence takes place may be quite different for different organs (*e.g.* character of gills, kidneys, &c.). One ontogeny is derivable from another, but when modification is introduced, it is not by the addition of a new total ‘ stage ’ at the end of the previous life-history, but by interstitial changes, so to say, either in individual organs or in parts of organs, and usually in quite early stages of growth and differentiation.

I have claimed that torsion arose in the free-swimming larval stage of Gastropod ancestors, and that by so arising it created the order Gastropoda; also that the marginal slit arose in an early post-larval creeping stage to meet respiratory difficulties then first encountered as a result of the mutation. I now claim that the hole of *Fissurella* arose by a modification of the marginal slit at a stage of development scarcely later than that of the slit itself, but at a later period in the phyletic history. By this I mean that the immediate adult ancestor of *Fissurella* was to all intents and purposes an *Emarginula* with marginal slit and long slit-band ; and that the slit was transformed into a hole very much as it is transformed to-day and at the same stage of the life-history.

We have an irresistible tendency when considering the evolution of living things to look for gradual changes—‘ By Nature’s gradual processes be taught ! ’ to requote Wordsworth—, but there is no getting over the fact that the conversion of a slit into a hole sooner or later involves an act of discontinuity,—a mutation. At the critical period in the evolutional process one generation had a migrating slit, and the next generation, or some individuals in it, changed the slit into a permanent hole. Now in an

organism provided with a free mantle which goes on growing through life, and preserves a slit margin as long as it grows, the mutation to form a hole must be just the same in later as in earlier stages of the migration, and no greater if it occurs at the beginning than if it occurs at the end. We never can be present throughout an act of evolution, for the simple reason that, until countless generations have passed, the mutation is an individual peculiarity, or a local variety, or something not yet sufficiently widespread to ensure our recognition of its significance. Nature's 'gradual processes' of evolution lie not so much in the absence of mutation as in the spreading of a mutation through the community. The nearest approach to witnessing such a process in our time has been the observation by entomologists of the spreading of melanism in moths.

In this address I have sought to keep morphological facts clearly distinguishable from interpretations, but I have also attempted to show that morphological facts require bionomical facts to elucidate their significance. On purely morphological grounds I attempted to show that we are under no intellectual necessity of concluding that everything new must arise late in the life-history, and the development of *Fissurella* shows us that to-day at any rate the marginal slit is converted into a hole at the very outset of the adult life. I am well aware of the fact that there are many other stable conditions of Zygobranchiate holes, and that in *Rimula*, for example, the hole, instead of being apical, is halfway between the apex and the margin. It therefore furnishes to superficial appearances a halfway house between *Emarginula* and *Fissurella*, and renders it perfectly possible, some would say probable, that the immediate ancestor of *Fissurella* was a *Rimula*, with a short slit-band, and not *Emarginula* with a long one. I submit that the existence of *Rimula* makes no difference to the problem of recapitulatory development as evidenced by *Fissurella*. There is a stage in the development of *Fissurella* when its hole is also in the middle, and it is commonly claimed that *Fissurella* on that account goes through a *Rimula* stage after its *Emarginula* stage. But it is equally true of *Rimula* as of *Emarginula*, that it possesses something which *Fissurella* at the corresponding stage does not possess, viz. a 'slit-band,' so that any representation of the definitely adult stage of *Rimula* is absent from the life-history of *Fissurella* as completely as is that of *Emarginula* itself. All that these three genera possess in common is a short transitory post-larval stage with a slit and no band, and it is at this stage that the slit is converted into a hole in *Fissurella*.

Under heredity we cover a multitude of things, and it seems to become increasingly clear that half the things which constantly occur in a given ontogeny, *i.e.* half the links in the necessitarian chain, are not predetermined by intrinsic structure so much as dependent on the operation of influences from surrounding or adjacent parts of the developing organism. At an earlier stage I suggested that the marginal slit itself may have been determined originally—and, I now add, may still be determined—by the pouring out of a horizontal stream of deoxygenated and poisonous water against the growing mantle-edge. Suppose now that in the series of generations between *Emarginula* and *Fissurella* the changing conformation of the body, associated with perpetual downgrowth of the mantle-edge and elevation of the visceral cone, should have gradually involved a

relative upward movement in the direction of the exhalant stream. Here without a doubt *Rimula* may find its real significance as a connecting link. The stream is horizontal in *Emarginula*, oblique in *Rimula*, vertical in *Fissurella*. The stream would then continue to play upon one point only, in *Rimula* halfway down the old slit-band, in *Fissurella* at its earliest base. So playing, it would keep the slit open at the same spot throughout and continue to discharge through the same gap. But the mantle, going on with its general growth, would soon prolong the edges of the slit beyond the range of any inhibiting influence from the cloacal stream. The edges would necessarily meet below it, and would there tend to resume their interrupted continuity. The mutation I have spoken of would thereby be accomplished, and its adaptive character would need no separate explanation: adaptation itself would have made the hole, and would have simultaneously ceased to make a migratory slit.

There is an old German proverb which needs to be hung over the mantelpiece of those of us who have a bent for speculation: *Behaupten ist nicht beweisen*. Nevertheless, if art is long, science is much longer, and of all sciences Zoology makes the greatest drafts on time for securing synthetic results. By ourselves in this field we can do nothing. We must critically assimilate the work of our predecessors and co-operate whole-heartedly with our colleagues, or we plough the sands. I trust that I have not misused the presidential opportunity and privilege by this mingled play of criticism and suggestion, and that it may help to clarify some of our evolutional problems. Even if every conclusion it expresses should turn out to be untenable, there are times when it is useful to throw the windows of the mind wide open.

ANCIENT GEOGRAPHY IN MODERN EDUCATION.

ADDRESS BY

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When the Geographical Association met at Oxford last spring it was welcomed, by one who knows the University well and has served it long, with a retrospect of geographical studies there, of which the theme was this: that geography, though in its modern guise it ranked among those 'new subjects' which an ancient institution was expected to tolerate, if not to embrace, was nevertheless of old standing there, and good repute; and that, while other branches of nineteenth-century science had established themselves in almost aggressive self-sufficiency, as additions—some might say accretions—to academic structure, geography had expressed itself rather in a modification of the whole point of view from which traditional studies were surveyed, and on which humanistic education was based.

Without any disparagement of the systematic training offered to those who desire it by the Oxford School of Geography, or of the conspicuous services of its first two directors, Sir Halford Mackinder and the late Dr. Herbertson, to geographical teaching in general, it may be claimed, I think, that this estimate of the place won for geography in a great university is of more than local significance. In the British Association (we do well to remember) geography, though not quite one of our original sections (as was the *history* of science), shared Section C with geology from 1835 to 1851; it was a great geologist, Sir Roderick Murchison, who advocated a separate geographical section, and became the first president of Section E; and it was in the friendly shelter of Section E that anthropological studies took shape in the next generation, till they matured into Section H in 1884. And such co-partnership is in accord with the profession of geographers themselves, that their subject is the coherent application of the methods and conclusions of other sciences, within regional limits, and—to be quite precise—within certain chronological boundaries also.

It is this claim for geography that it co-ordinates regionally the results and conclusions of other sciences in respect to the natural phenomena of each and every region, and that, including as it must Man's activities among the factors with which it is concerned, it stands in a peculiarly intimate relation with history, that brings it under the special notice of the art and applied science of education, but at the same time has made it so difficult in practice to assign to geographers their proper place and

function in educational schemes. And having had now about a generation's experience of some aspects of this problem, I am about to submit some reflections and a few proposals in regard to those aspects of geographical research, and applications of them to educational uses, with which I have been personally concerned. They are not those which have hitherto received the widest attention, and to some people they may not seem of the widest utility or significance. But for this very reason, if I succeed in making good any suggestions in this special department, they may serve *a fortiori* to commend more liberal recognition of other geographical studies, of which the value and utility are admitted by common consent outside the syllabus and the time-table.

The 'Next Phase' in Geographical Teaching.

We begin to hear rumours about the 'Next Phase in Education,' and my colleague in Section L will no doubt tell us just what that means. Now whatever else it means—and involves, when it comes to pass—it is at all events an occasion for revising old estimates of what is practicable, in the light of new notions of what is desired, with the help of immemorial ideas of what is desirable because essential to citizenship. And as the 'Next Phase in Education' means at all events this—to quote 'Circular 1397' of the Board of Education—that schools are to be reorganised 'to secure for all pupils a break at eleven, and a fresh start at that age on a definitely new stage in education,' it is clearly urgent that those who have views as to what geographical training that 'new stage in education' shall offer should express them without delay.

A generation ago—and perhaps even less—the establishment of a 'break at eleven' for all pupils would have meant serious risk that in the 'new stage' little would be taught except subjects of obvious and immediate utility :—'science and art' subjects certainly; stenography probably, but as a 'practical' alternative to music, or by way of 'physical drill' for the fingers; modern languages, perhaps, but treated linguistically and conversationally, as vehicles of information or 'orders' rather than ideas. That risk is still real; but I think it is less insistent than it was, mainly because the facilities already offered for a high type of secondary education to children from all kinds of homes, and still more for retrieving omissions through adult classes, and (may we not add ?) the humanising devices of wireless transmission and mechanical record, for disseminating first-rate and first-hand guidance and stimulus to lonely souls, and mere parents, have gone far to break down obstacles and remove misconceptions as to the methods, objects and significance of relatively advanced studies. And this is a change of outlook which has conspicuously affected those subjects and aspects of education which suffered most severely in the past from defective exposition—from 'the second-rate at second-hand,' as an Oxford satirist of 'extension' put it.

It is, if I am rightly informed, to be one of the principles of the 'Next Phase in Education' that from the age of eleven onwards the programme of studies shall be progressively differentiated in accordance with the faculties and proficiency of individual pupils. This on the one hand should mean that for those whose natural bent is towards handicraft

there shall be more liberal recognition of the dignity and potential excellence of craftsmanship, with all that is implied in the adaptation of what used to be called the ' liberal arts ' to widen appreciation and deepen sensibility in the craftsman-to-be, by familiarity with the masterpieces of his own and kindred crafts. That the advent of the ' Next Phase ' should have been signalled by the establishment of a Royal Commission on National Museums is of good omen in this respect, for there is much room for correlation of studies and differentiation of teaching practice here. On the other hand we may hope for, and claim, greater freedom of treatment for literary, historical and scientific studies alike ; opportunity for fresh combinations and closer interlock between related subjects ; less formal class-work and mass-distribution of knowledge, but more team-work and ' mutual improvement ' (to revive a gracious memory) among the students themselves ; less observance of time-table and syllabus, wider range and more spontaneous choice of individual reading. In geography let us hope for greater familiarity with the writings of the great travellers, less dependence on textbook pemmican. As Mrs. Beeton says of another kind of chicken broth, ' the best fresh meat only should be used.' And as main cause and (in turn) inevitable effect of all this, let us insist on sincere relaxation of the tyranny of external examiners and deliberate confidence in the considered estimate of the teacher, as to the results of all this on the child.

In the years before eleven, too, may we hope for changes which in fact, if not in name, may do something to obliterate the divergence between what have hitherto been only too truly contrasted as ' elementary ' and ' preparatory ' kinds of education. And herein the mere geographer will, I think, demand two things : *first*, in ' preparatory ' schools, hitherto so-called, such recognition of the ' preparatory ' value of geography as has already been accorded in many of the best ' elementary ' schools ; in particular, correlation between a coherent programme of geographical teaching and those literary and historical studies which have in the past been one of the best features of ' preparatory ' schools, though at some cost to the preparation of their scholars for transference to any but the conventional ' public schools.' *Secondly*, in ' elementary ' schools, which will now be indeed ' preparatory ' to the ' new stage of education,' may we not ask for careful reapportionment of the principal groups of studies and aspects of learning ; elimination of technical elements and wage-winning considerations altogether ; and concentration on the rather small number of really ' primary ' studies, with the maximum of interplay between them all ? For it is at this stage that we have most chance of accustoming a child to ' see life whole ' as well as ' steadily ' ; and the fewer the compartments into which it is found necessary to disintegrate education, the greater the security that nothing really important has failed to fall into some one of them.

Now somewhere within those principal groups of studies which make up the programme of education, geography—and ancient geography in particular—has its reasonable place ; and the question to which I am trying to frame an answer is as to the principles on which that just place is to be assigned, and in what working association with other subjects. If I digress at this stage into what will seem to some to be platitude, and

to others rather remote speculation, my reason is that, as long as such differences of opinion about it are possible, the subject is not exhausted, perhaps not even defined; though I have no expectation of doing more than to make my own point of view intelligible.

The Place of Geography among Aspects of Learning.

Geography, as its name indicates, is the systematic description of this earth of ours. But description is not an end in itself. The end, to which it is the means, is a science of the earth, an understanding and interpretation of its meaning. Like all other departments of science, it presumes two things: an intelligence to which this significance is interpreted, and what I will only describe now as intelligibility of the facts of observation in relation with each other. In geographical science the relation of these facts with each other is their relation in space; the geographer ascertains, records, compares and interprets distributions, the arrangement of things on or in relation to the surface of the earth. Geography, that is to say, asks two questions in respect of each geographical fact: *where* is it observed? and *why just there?*

Obviously, in this general sense, geography is the coequal sister-science of history, which studies and interprets the relations of events in time. History originally meant (as its name also indicates) the process of following or tracking something which has gone before, and left trace or trail; and is applied, like the name geography, to the recorded result of such 'following-up.' Like geography, it begins with description and proceeds to interpret. But whereas the geographer's observations are for the most part verifiable at will—for he can go back to a place and see it again—the historian is always to this extent behind the times, that he can never catch up historical events at all, still less can he have them repeated, however closely the new devices of phonograph and photograph may simulate such repetition. It is a notable accident of speech that 'history' should thus disclaim what 'geography' achieves, namely, direct transcription of the facts which it studies. History is always looking for something that is no longer there; geography has the earth ever present, in all its 'young significance.'

But the philosopher is aware—and the geologist and the meteorologist confirm him—that 'you cannot cross the same river twice.' Every relation between objects in space is bound up with a relation between events in time. Consequently every geographical fact has its historical aspect, and every historical fact its geographical aspect. What we group together as the 'historical' sciences, from the most specialised histories of human achievements—mathematics or music or morals—to the most general study of sequences among events—in astronomy or geology—are inevitably also 'distributional' sciences, because all the facts and events which they study happen *somewhere* as well as *somewhen*.

All human history, then, is regional history, and loses value and meaning when its geographical aspect is overlooked; all geography, on the other hand, and (most obviously) all human geography, depends for its significance on the consideration that it is contemplating, not facts only, but events with causes and effects; processes, of which our

map-distributions are momentary cross-sections, needing to be recombined, like the microtome-layers of the anatomist or the successive snapshots of a film, if their significance is to be recovered as phases of an event. Thus we speak of the historical *duration* of a glacier as an obstacle to traffic over a mountain pass; and of the geographical *distribution* of Greek city states or Parliamentary institutions.

It was indeed this coalescence of geographical and historical outlook and method, late in the eighteenth century, which made possible to von Humboldt and Ritter our modern geography, the study of the distribution and interrelation of terrestrial processes; and reacted, through Lyell, Darwin, Lubbock and Pitt-Rivers—to give only British names—on the humanities, by supplying a method of geographical analysis for what are popularly called historical *situations*.

No one, I hope, will have been led by any part of this argument to suppose any intention to ignore those other aspects of science—of intelligence exercised on the intelligible around us—which are concerned neither with relations in space nor with relations in time, but ultimately and sometimes quite obviously with quantities and qualities; all those observations which go to make up the Physical Sciences; and all conclusions and results of the kind which Aristotle was illustrating when he said that 'fire burns here as in Persia'—and he might well have added that 'fire burns now as it burned Persepolis or Troy.' In respect to all those expressions of *how* things happen, or *how* they are composed, the historical and distributional sciences stand in the relation of applied sciences to the 'pure sciences' of physics, chemistry and physiology: accepting and employing their conceptions and interpretations, like their vocabulary and notation, as a gunner employs range-finder and explosive to solve his regional problem of making this projectile here hit that target over there. This intellectual outlook is quite consistent with the possibility that any occasion of gunnery may suggest fresh problems to the physicist or the chemist, or offer them significant data; and may even do so by reason of local and temporal conditions. It was a sound instinct, as well as wholesome criticism of somebody's educational technique, that made the schoolboy bring into class a lump of wayside chalk and beg that by the method demonstrated yesterday carbon dioxide might now be made out of *this*.

Similarly, those aspects of science which are concerned with the estimation and interpretation of values—with relations, that is, as irreducible to quantitative expression as they are to conjunctions of region or period, and wherein the notion even of quality parts company almost at the outset from anything that has significance for a chemist—have nevertheless ultimately this point of contact with geographical and historical science, that all the values with which they are concerned are values-to-man, and consequently are, as phenomena, characteristic of—perhaps even peculiar to—terrestrial life, and to a relatively recent phase of it. Indeed, when we speak of these sciences as the Humanities, we mark their distributional and historical limitations, even while we recognise their high rank among aspects of knowledge and their supreme significance to ourselves.

Now of these three main groups of studies: the Human Sciences and

the Natural Sciences, in the stricter sense, are alike systematic, and consequently collateral studies, only touching each other at their margins. The remaining group, on the other hand, both in its historical and in its distributional aspect, derives its content and its data from any or all of the systematic sciences. There is a historical aspect of botanical study, for example, the palæo-botany of fossil plants, linked with the field botany and plant physiology of to-day by survivals of archaic forms of plant life ; and there is a geographical aspect, the study of plant distributions, with its intimate bearing on questions of descent and affinity, and its corollary, œcology, which I take to be the special study of co-distributions.

Similarly, there is a historical aspect of ethics, and æsthetics, and no less a geographical aspect, brought latterly to some notoriety by current controversies about the 'diffusion' of ideas, as well as of techniques, the latter being but the expression of ideas in the solid, in artefact instead of behaviour.

And throughout these distributional aspects and treatments of the data of systematic sciences, both historical and regional considerations are ever present, ubiquitous, inextricable from each other. At most we may recognise by an obvious paradox that the geographer is concerned with distributions which are relatively stable in point of time—land forms, vegetation types, lines of communication—and the historian with sequences which are relatively stable regionally—the doings of this or that body of people more or less permanently sedentary within a particular complex of geographical conditions. The geographer, that is to say, leaves the larger history of his land-forms to the historical geologist, of his vegetation to the historical botanist, of his lines of communication to the archæologist, for demonstration in detail ; and devotes himself to the diverse regional combinations which result from their respective distributions, which are all more or less world-wide. The historian similarly leaves the larger distribution of these same factors to the student of their world-wide occurrences, and concentrates his attention on the sequence of events in the 'region' where those are relatively unchanged in time, and consequently compose the permanent regional stage on which the processes of history occur.

But it follows from this, that, in the same way as the geographer fails of his duty if he overlooks the fact that, from mountains and the tides to town-planning and aviation, he is in fact dealing with distributions which are changing, though their rates of change vary almost infinitely, so the historian fails to appreciate the significance of historical events if he ignores those historically permanent limitations within which all human revolutions occur, and to which the most stable of human institutions owe nearly all the stability they have.

To take an elementary instance. Man, it has been truly said, 'does not live by bread alone.' Where the lagoons of Ostia and the *Via Salaria* stood in the primitive economy of the city of Rome and in its relations with its inland neighbours, and the salt-mines of Hallstatt in the commercial and cultural relations of the Danubian cultures, there stood Alexandria's command of the salt-works in Ptolemaic Egypt, the long significance of Palmyra in the history of the Nearer East, and the *gabelle* in the rise and fall of a national monarchy in France ; and it is without

surprise that a geographer reads in the newspapers that one of the first public acts of the new Nationalist Government in China is to arrange with the 'foreign devils' for the supply of the same ill-distributed but indispensable element in the daily food of its subjects. After five years of anarchy the salt supply must have run rather low.

That this kind of correlation between historical and geographical studies is more widely valued and practised than formerly is shown by the large current output of what are generally described as *Outlines of History* or *Histories of Civilisation.* Of this whole class the characteristics are three. The first is the very wide range with which these books attempt to deal, in respect both of area and of period. If they do not always 'survey mankind from China to Peru,' they frequently begin with the Ice Age and end with the Great War. They deal, that is, with what Mr. Wells elsewhere describes as *Mankind in the Making* and Mr. Marvin as the *Living Past* or the *Unity of Civilisation.* Secondly, they are concerned mainly with social, economic and cultural achievements, originating among, and generally affecting, the population of this or that natural region as a whole; and to keep the broad lines of this presentation clear they pass over much detail the chronological interest of which made it attractive to those earlier historians whose monuments are the eighteenth-century *Art de vérifier les Dates* and Clinton's *Fasti Hellenici.* Thirdly, they relegate biographical material to biographies, and the details of political history to the special large-scale histories of particular states and periods. The focus of human interest has shifted from individuals to populations. If they have one defect in common, it is that they not only forswear hero-worship, but obliterate leadership as a historical factor.

Precept and Example: 'Historical and Geographical Instances.'

I set out to speak about ancient geography in modern education; and if I seem to have spoken about almost anything else hitherto, it is with the object of presenting certain considerations in regard to modern education, and also to ancient geography, which seem to me fundamental, and also so obvious that if I carry general agreement in regard to them, what I really wish to submit follows as an easy conclusion.

We boast, and rightly, that we try to make education practical and useful; that it is a means to an end; and that its end is the establishment of successors to ourselves at least as intelligent, efficient, responsible—*free*, in the old Greek sense of freedom (*eleutheria*) as 'grown-up-ness'—as we are ourselves; and, as we severally hope, a great deal more intelligent, efficient, responsible and free, than most of our own fellow-citizens. With this end in view we expose the pupil-that-is and the citizen-that-is-to-be to a graduated sequence of experiences and occasions, selected to give appropriate opportunities for that exercise of his natural abilities, that almost continuous process of reasonable response to his surroundings, which we call *life*; which (short of criminal oppression) we cannot prevent the growing child from exercising, but which by neglect or mistake or mere muddle, which is bred of both, can be, so easily, exercised carelessly, perversely, irresponsibly, with results familiar to us all.

Now those selected sequences of occasions and experiences, which we

call educational courses, are of three clearly defined sorts, corresponding with the three principal groups of sciences and aspects of all knowledge with which I began. If I take them now in reverse order it is because I shall only come down to detailed criticisms and proposals in dealing with sciences historical and distributional.

In the first place, then, we train the citizen-to-be in citizenship, which I take to be the modern technical term for what a Roman called *civilitas*, and some pioneers of our own Renaissance and Reformation called consequently *civility*. For a Roman, a man was *civis* when he was what in Irish cottages is called ' biddable,' apt to ' take notice '—as advertisements to trespassers say—of the fact that he has neighbours like himself, with reasonable desires, habits, conveniences, like his own ; and that, in brief, a man gets most out of life as he puts most into it, in his doings among such neighbours. A man who has the qualities, outlook and will of a *civis* is described as *civilis*, and also as *liber*—a more difficult word, probably related to the Greek word for ' grown-up-ness ' already mentioned ; so that *civilitas* and *libertas* were aspects of the same quality of ' citizenship.' To propagate these qualities was to ' civilise ' ; and from their exercise resulted—and results—' civilisation.' To elicit them among the spontaneous impulses, efforts, aspirations of younglings who, being bred of ' civil ' stock, have presumably the root of the matter in them, is the primary task of education ; to confront them with elementary social facts, in nursery and kindergarten ; to give occasions for estimating values, duties and rights, for dealing with situations and problems in which they necessarily comport themselves as ' members of a realm of ends,' as citizens in a city which grows with their growth.

What the statutes and bylaws, so to speak, of that adolescent community are to be depends, as we know, only partly on political and moral principles, and far more largely on custom. But as custom is of necessity both regional and temporal, it is to historical and geographical considerations that we recur when we are challenged to explain our own code, or to excuse those inconsistencies in it which are naturally more obvious to novices and newcomers from the ' next generation ' than to old-stagers and ' men of the world ' like ourselves. For these purposes we have recourse to records and traditions, reinforcing or mitigating precept by historical illustration ; appealing from abstract to concrete, from morality to hero-worship, as ancient teachers have done before us, in parable or tragic drama. Of history it is notoriously the besetting sin to moralise and become didactic ; and against this tendency it is worth while to consider any reasonable precaution.

Secondly, we have to present analytically the principal factors in the processes which make up the pageant of external nature and the methods by which they are detected, measured, controlled, and applied to human ends. Here, as we have already seen, questions of distribution cannot arise : ' fire burns here as in Persia.' But from the moment when pure science passes over into any kind of practical application, considerations of place and time reappear ; for in wild Nature all processes and all material resources are regional ; and it is fundamental in human interference with the order of Nature that it displaces things and disarranges that order. All agriculture is displacement and replacement of natural

vegetation—we remember the cynic's definition of weeds as 'God's plants growing where man doesn't want them'—; all engineering, displacement and replacement of the solid earth or its ingredients; all commerce, redistribution of natural resources or our rehandlings of them. At every stage, and more insistently and obviously in each higher stage, we are called upon to 'think geographically'; and most of all when we come to the consideration of man's dealings with his finest tool and worst obstacle, his fellow-men. To take an instance from current political discussion: what do we mean by a 'congested district,' and how do we propose to deal with the population of a coalfield where there is no more coal? It is a question, once again, of redistribution, and it arises from a fact of redistribution in the past; for the coal has gone somewhere.

Thirdly, then, it is our business to train inborn faculties of observation and inference to make their own analysis of actual regional circumstances, and to present these as the momentary current phase of many interacting processes, such as the special sciences are concerned to interpret severally, under the limitations of the relatively stable structure of the given portion of the earth's surface to which the citizen-to-be has access now; and maybe he will never have the chance to deal with any other. Modern geography accordingly adopts increasingly, and almost inevitably, this regional method of study and exposition as being at the same time the most efficient and the most economical in point of time. It is a method which presents close analogies with the use of 'set books' in the teaching of languages. There a brief analytical study of the elements of grammar leads directly to the exploration—for to the pupil it is nothing less—of the 'fine confused feeding' of grammatical constructions as they flowed from the pen of Cæsar or Xenophon. In the teaching of history it is the same. The general equipment of needs, motives and aspirations which actuate ordinary people is presumed to be familiar, and a beginning is made at once on episodes and periods which exhibit such people working out their life-history among the resources and restrictions of a homeland, which is in the first instance that of the pupils themselves.

Ancient Geography of the Homeland.

Yet even at that elementary stage in which the common aim of all concurrent 'courses' of instruction is to make the child familiar with the leading features of the 'homeland,' historical retrospect comes to play a part of ever-increasing importance; if only because in our time those very features are being profoundly modified. Artificial, and for the most part urban or suburban conditions, are rapidly encroaching on what was recently rural. Habitual access to unspoiled countryside, and familiarity with country life, become more precarious and difficult, and most of all for small children. Yet what we call 'unspoiled countryside' in most parts of this island is itself in great measure artificial; the result not so much of the centuries of almost unimproved farming, as of those two past crises—as revolutionary in their effects on the 'countryside' as anything that followed until the last hundred years—the Saxon Conquest with its intense exploitation of the forested lowlands; and, before that, the coming of any kind of agriculture at all, restricted though this earlier

exploitation was to the drier, and for the most part therefore to the higher-lying, districts, oases and natural clearings in the dense overgrowth which is now so hard to reconstruct even in a trained imagination. Fortunately in our timbered hedgerows, at all events, the principal elements of that ancient regime remain accessible to many of us, and English taste in the treatment of urban open spaces—for example in the London parks and squares—makes this feature in ancient landscape more familiar still. Characteristic data, that is, are still available for the reconstruction of that ' unspoiled countryside ' for each principal period of national history, without which the familiar episodes of King Alfred at Athelney, Hereward in the Isle of Ely, the parkland fates of King Edmund and William Rufus lose much of their historic value, because they are bereft of their geographical setting.

In many parts of the country, I am gladly aware, I should be preaching to the converted if I were to elaborate this kind of correlation between ancient geographical conditions and ancient life. Whether the geographer or the historian takes the initiative in each instance seems to me to be matter of indifference, provided *first* that the other colleague responds; and provided *also* that initiative, response and collaboration occur as publicly, frankly and naturally as educational good manners allow. Few things are so stimulating to a class or a whole schoolful of pupils as to realise that the staff too is a team; that the divisions between aspects of knowledge are as arbitrary and artificial as the segregation of children into classes; that learning permeates wherever there is an observant eye or an attentive ear; that information sought and found sinks deepest and lasts longest.

If, then, it be our main object in teaching our national history in our schools, to bring up citizens-to-be with some appreciation of historical perspective, we cannot forgo that alternative line of approach which inquires what the homeland was, before it was made homelike as we know it, and what its part has been in shaping the careers and the outlook of our people in the past. This, in its simplest illustration, is what I mean by the function of ancient geography in modern education; and it will be seen that there is no phase of instruction so ' primary ' or so ' advanced ' that it can be regarded as superfluous or inopportune.

But it would be a very imperfect preparation for citizenship which included the history of British people only; for the appreciation of our own literature, or for the right enjoyment of leisure—as Greek educators called it—if the mental horizon so lay as to reveal no drama before Shakespeare, no epic before Milton, no history before Froissart or Clarendon. Great as our national literature is, it owes much of its greatness and originality to the fact that it has been so apt to learn; that it has taken into its own texture so much of the best from other great literatures, from Israel, from Greece and Rome. With our history it is the same. It stands embraced by the history of Europe, and sustained on the history of the Mediterranean world and the Nearer East. We cannot afford to read it or to teach it by itself. It presumes for its interpretation that the world is wider than these islands and older than modern history. If we would see life truly we must needs see it whole.

Ancient Geography in 'Classical Studies.'

Now it happens that these two cultures, each with its characteristic ideal of what man's life may come to be, represent supreme achievements of humanity within natural regions and regimes strongly contrasted both with each other and with those of the British homeland. Greek life and all its legacy to us are man's solution of the problem not merely of maintaining life under Mediterranean conditions, but of realising to the full what life under those conditions might become. We are only beginning to know, through the discoveries of Huntington, Antevs, Pettersson, and Brooks, among others, how exceptional was the conjunction of physical circumstances which made the Mediterranean region itself, and in particular the Greek cradlelands round the Ægean Archipelago, unusually favourable ground for such an adventure; and how essential it is to reconstruct, from all available sources of evidence, that picture of a region not only almost unspoiled as yet by man's enterprises, but temporarily competent to repair his ravages and postpone his worst derangements of its natural regime. Conversely, as our knowledge of the later symptoms of decline and disorganisation grows, as we see it pictured in Rostovtseff's *Social and Economic History of the Roman Empire*, the fact of a general hardening of the physical conditions—for which there appears to be sufficient evidence, and full corroboration from the course of events in North-Western Europe—goes far to explain the perplexing way in which well-considered remedies failed of their effect, and sometimes even aggravated that 'distress of nations with perplexity' which was imminent already in the last century of the Roman Republic. Both in its adolescence and in its old age—if we may recur to phrases which no one here will mistake for arguments—the Greek view of life, and the Roman too, which was so profoundly influenced by it, are revealed, as we come to know the circumstances, as the philosophy of a glorious adventure, of experiment in a new phase of exploitation, of co-operation for fresh social and political ends, of adjustment of inherited technique and behaviour to unexplored conditions and occasions. If ever man conquered Nature by stooping to reasoned conformity with Nature's restrictions, it was here; if ever invention was the child of necessity, it was in the strict school of Mediterranean and, above all, of Ægean environment.

This environment, however, happens to be one which illustrates with exceptional facility that interaction of geographical factors which makes all natural regions what they are. Partly no doubt for that reason, but mainly on account of the special interest and importance of its human geography, the Mediterranean region has been long and carefully studied; and is, I think, recognised by many teachers of geography as one of the most valuable for analytical study. Further, at almost all periods of history subsequent to the 'classical age' the Mediterranean has had considerable historical significance; and this significance has varied widely enough, through the changing relations between the region itself and its neighbours, to make the comparative study of its economic and political vicissitudes exceptionally instructive. Most important of all, though physical conditions have not apparently been quite uniform throughout, they do not seem to have ever varied sufficiently to modify

the fundamental economic relations between man and natural resources, or those elementary social units by which the food-quest and other essential activities have been carried on. A modern Cretan village is amazingly like its Minoan predecessor, at all points where we can compare their arrangements and economy. In secluded districts Greek city states have preserved their corporate life, and even their constitutional structure, from classical to modern times, and more of those communities have been first remodelled since their release from Turkish rule than were disorganised by Turkish conquest.

There is therefore, I think, good reason to urge that at whatever stage the history of the 'classical' civilisation is included in the programme of education, the regional geography of the Mediterranean basin should be its customary counterpart, and that the two courses should be carried on with habitual cross-reference to each other. And conversely, when the proper moment comes for the study of the Mediterranean basin geographically, the history-course should be planned so as to supplement it in respect of the more significant achievements of Mediterranean peoples, and also to illustrate—what can nowhere else be attempted over so long a range of time—those effects of long-continued human occupancy which have disfigured some Mediterranean lands beyond repair and paralysed the later periods of their history.

Ancient Geography in 'Simple Bible Teaching.'

For the earlier periods of history, and for that other great factor of our own civilisation which is our inheritance from the Ancient East, the difficulties of correlation, which at first sight might appear greater, are in fact insignificant. For here we have ready to hand a great textbook already in compulsory use; at the same time great literature and great history; a great classic of Oriental life and its surroundings, and a masterpiece of English prose; the historical books of the Hebrew people, in our own Authorised Version. With this example before us of what is not only practicable but prescribed irresistibly by public opinion as a fundamental element in public education, and with the knowledge we have of the profound influence which, in this shape, ancient geography, ancient history, and ancient literature alike have had in the formation of our national outlook, can anyone fairly say either that ancient geography, so conceived and illustrated as the regional aspect of great historical events, is without direct utilitarian value in modern life, or that there is no room for it in the curriculum of our schools?

We all know very well that the Old Testament is sometimes taught more as if it were a collection of parables or allegories than as geography, or history, or even literature; but I venture to suggest that it is in proportion as we teach it as geography, as well as history and literature, that its value as parable or allegory will be most surely appreciated. The more impartially and objectively we bring to Hebrew history and literature the geographical commentary and illustration which we devote as a matter of course to the records of other Great Peoples, the more thoroughly we accustom ourselves and our pupils to treat these texts as a current source for incidents and illustrations of certain phases of human adventure, the more conspicuously do their remarkable qualities, both as history and

as literature, emerge; the more surely their contents take their proper place, not as legends of an unearthly wonderland, but as contemporary record of a peculiar people, confronted, in a region no less remarkable, with the most momentous crisis that can befall any people, at a crucial period in the growth of the civilisation which is our own.

If anyone should object that this kind of study is not easy, and propose to postpone it until (to borrow a familiar phrase) 'he shall be certified that the child shall well endure it,' I would reply that in some people's experience neither the Authorised Version nor the classical literatures of Greece and Rome are easy reading. Yet I do not find that admitted difficulties and even uncertainties of interpretation, or the fairyland remoteness of their setting, prevent people from insisting that all children shall be confronted with the one, and all whose parents can pay for it with the others as well, at a surprisingly early age, and with the deliberate conviction that it is (among other things) just this unfamiliarity which makes acquaintance with them so salutary. And the lavish way in which popular books on Biblical subjects, and places where Biblical teaching goes on, are garnished with pictorial reconstructions of Biblical scenes, suggests to the mere geographer that the need for what is now suggested has been in some measure anticipated by specialists.

At first sight—or rather, as it has been commonly presented hitherto—the homeland and the history of the Hebrew people offer less obvious opportunities for this kind of correlation of historical and geographical studies. But in two fundamental aspects that people supplies illustrations of the same interplay of factors, with characteristic—indeed almost unique—results. In Hebrew literature we have what is almost wholly missing in the Greek instance, an autobiography of an immigrant people during the whole momentous process of acclimatisation to regional conditions strongly contrasted with those out of which the newcomers came. Nomad pastoral tribes, compactly organised in one of the most stable of all known types of community, and austerely habituated to do without almost all the characteristic resources of the 'good land beyond Jordan,' a 'land of corn, wine and oil,' 'flowing with milk and honey,' found itself intruded into a sedentary agricultural regime, ancient, attuned to those regional surroundings, already composite, and enriched by habitual intercourse with highly civilised neighbours and great centres of industry and organised experience. Confronted with such novelties and such temptations to 'enter in and possess,' how were such people to behave? The story of their experiences is one of the great dramas of the world; and the record of it, in our Authorised Version, one of the supreme achievements of English literature.

That is one aspect of Hebrew history and geography, its domestic aspect, as an internal reconciliation of Folk with Place. The other aspect to which I have to draw attention is external: the reaction of acclimatised Israel to the forces which were shaping the world-history of its times. From no single standpoint is it more illuminating to survey and take stock of the great civilisations of the Nearer East than from the miniature states which centred in Jerusalem and Samaria; and the fateful separation of these from each other is itself an early symptom of the distractions which those giant neighbours caused.

Here too, as in the Mediterranean lands, there is the less need to give illustrations in detail, since the last twenty years have completely remodelled our equipment for handling these regions and periods in every degree of elementary and more advanced treatment. The main results of modern Biblical and Oriental scholarship, of geographical exploration in the Nearer East and of excavation on ancient sites, are as nearly common property as the production of popular handbooks can make any form of scholarship. And, thanks mainly to the value rightly assigned to these studies in American education, the literature accessible in English is now of as high quality as in any other language. It is no longer honest to plead ignorance of German as an excuse for shirking a public duty. Further, since our own country has incurred the obligations of its mandates for Babylonia and Palestine, in addition to its responsibility for the security and well-being of Egypt, we cannot plead that the geography of these regions lies outside the scope of political duty, or the daily needs of every one of us. We may not want to understand those countries or their peoples ; but as things stand, we neglect those studies at our peril : and, at least, let us provide for our children.

There is another reason why the human geography of the Nearer East and the Mediterranean region has especial value in education, both as a separate study and to illustrate by comparison that of the homeland. Though the Western Mediterranean has an exceptionally pleasant climate for nearly half the year, and the Eastern for several months, large parts of the Near East are less fortunate, and some districts have a regime of Continental severity. Resources in soil and minerals are even more scantily distributed ; natural communications are difficult by land, the Mediterranean sailing season is restricted, and the rarity of perennial streams precludes inland navigation such as Central and North-Western Europe enjoy : it was as natural marvels that Nile and Euphrates were famous. Up to a certain point, and in certain highly specialised directions, cultures could and did mature in such regimes. Beyond this point, however, the attempt to do more imperilled what was won already : the margin of safety was never large, and the greater risks were the least well ascertained. External enemies came and went ; famine, local if not general, was never far off. In other words, Man and Nature in these regimes were very closely matched. *Where* Nature was locally more bountiful, as in Egypt, or Ionia, or Campania, or *when* regional conditions were more favourable for a while, as seems to have happened in the centuries from about 900 to 250 B.C., and again from about 900 to 1400 A.D., memorable advances in well-being were made and maintained for a while in face of relapse into austerity. Each however was achieved, like our own industrialism, at a terrible cost in ‘ wasting ’ assets, timber and soil in the ancient world, fuel and other minerals in the modern, more hopelessly irreplaceable still. Here is a ‘ lesson of history ’ only too likely to be overlooked, if it is not reinforced as a geography lesson.

Present Discontents.

I am well aware that the correlation which I have proposed will be regarded as something of a revolution in the teaching of ‘ classical subjects,’ and also that there are historical reasons for the methods

actually employed. More than fifteen years ago I had occasion to note (*Geographical Journal*, October 1912, p. 358) that certain omissions in the list of work submitted to the research department of the Royal Geographical Society 'would probably have been avoided if the study of geography in the older universities had been more closely associated with the historical studies which figure so largely there,' and that 'the present divorce is probably inevitable so long as the study of historical and literary subjects is regulated so closely, as it seems to be, by the requirements of the Civil Service examination; and as long as those examinations assign to geography the quite unworthy place to which it is restricted now.' Since the year 1912 there has indeed been improvement in detail, but no serious reconsideration of policy. If I may judge from experience both of examinations in history and in geography, and of informal conference with teachers and taught, what passes for 'historical geography' is still one of the weaker aspects of the geographical course, while what has been described as 'geographical history' is hardly attempted at all. Questions, rarely set, are still more rarely answered. Every examiner, and most teachers, know quite well what that means. What a piece of window-dressing is the familiar rubric that 'sketch-maps should be added where possible'! What flights of imagination occur, what skeletons emerge from their cupboards, when such sketch-maps are 'attempted'!

In discussions of elementary training we hear a good deal of the co-ordination of brain, eye, and hand. Why is it that as we ascend our educational ladder this primary necessity seems to be progressively ignored in the study of the humanities? With every allowance for the disciplinary value of games—often so highly 'organised' that their value as play or even as recreation begins to be doubtful, and some of us wonder why they are not frankly included in the time-table as 'alternatives' to music, carpentering, and natural history—such lack of manual dexterity as I have described is a serious defect of scholarly equipment. It is only not realised as such, because the chief employers of the 'finished' output of the humanistic courses in our universities are still themselves so inexperienced in graphic methods that many of them would have some difficulty in understanding a fully illustrated report on any regional topic. Statistics in tabular form have a certain impressiveness, and persons of vivid imagination claim the 'gift of tongues' in interpreting them; but what would happen to a speaker in Parliament who illustrated his argument with a map?

Yet in every other aspect of learning and advanced study, competent use of its special symbols and notation is an elementary prerequisite. A Grecian who boggled over Θ and Φ, a mathematician who misused a bracket or misread a decimal point, a chemist who confused *Mn* and *Mg*, a botanist who failed to draw recognisably the structures composing a flower, would, I think, have short shrift. But it is amazing how ill-equipped are most students of literary or historical subjects when it is a question of describing anything otherwise than in grammatical long-hand. It is not merely that they are poor draughtsmen; it is rather that they do not do their thinking about regional matters in such fashion that geographical symbols can express it. Rome, Athens, Paris, Vienna, York are to them abstractions such as *Mn* and *Mg* might be to a bookworm

who 'read chemistry' in an encyclopædia, but never handled a test-tube. And this raises a doubt whether that appearance, and even parade, of accuracy in other parts of their work, in chronology or the technique of archive-hunting, necessarily presumes that insight into historical processes which it is often supposed to imply. So too, at the other extreme, there have been both surveyors and big-game hunters who did not do much for geography. Yet, considered merely as a test of those qualities of co-ordinated craftsmanship, accurate observation, and clear concise statement of relevant facts, map-making ranks high. As I have had occasion to say elsewhere, 'a finished map is a scientific document, but it is also a work of art; to its scientific value, its completeness and accuracy, it adds the value which is given by style, the grace, which in a map, as in speech or writing, or any art of expression, is perhaps best rendered by its old Latin name of *eloquentia*; for it is the grace of *speaking out.* A map, no less than a despatch or a poem, has to give a message, without parade, or digression, or confusion; in the fewest and most unmistakeable symbols, which have the merits, and also the defects, of all symbols, and are good servants only in trained and sure hands. And what is true of a map, the geographical document in its simplest and most purely geographical form, is just as true of other geographical work, which is all a more or less explicit commentary on maps, in literary form, or hints for the comparison of maps with one another. All work of this kind is a work of art; the geographer puts scientific material into it; but he puts something of himself into it as well; it is (as we say) *his* work; and we are right, I think, in taking into account, as geographers, the form into which he casts it, the geographical *style* which is his.' (*Geographical Journal*, October 1912, p. 363.)

This is one reason why I have concentrated my advocacy of a more liberal acknowledgment of the geographical aspect of all historical studies, on the special instance of ancient geography; for it is in those compartments of our educational system where ancient history holds the most honoured and responsible place, that indifference to geographical considerations has lasted longest and most generally. And so long as a numerous and influential class of public servants and legislators is recruited from those compartments, so long will the geographical aspect of historical study continue to be overlooked, merely because the responsible people have had little or no personal experience of it. Even so observant a traveller and so scholarly a statesman as Lord Curzon, already President of the Royal Geographical Society, cut short a discussion of the place assigned to geography in the Civil Service examinations with the question what there was to complain of in the questions actually set.

But it is useless to encumber existing programmes of university study by the addition of formal geography to the subjects already prescribed. To this extent there is reason in an objection still occasionally heard, that geography is primarily and properly a school-subject, and that university teaching may and should assume adequate knowledge of its essentials. That indeed might be all very well if it were the fact that adequate geographical study had been the birthright, rather than the good fortune, of candidates for admission to the university, and if universities took the same trouble to require this prerequisite as they do with subjects in whose indispensability they really believe. And

meanwhile the contradictory objection finds voice, that geography is (for this or that reason) so unsuited to school teaching that it is best postponed till after leaving school.

Here again let me begin with the thick end of the wedge, and insist that while very considerable progress has been made in primary and modern-side-secondary education, in the provision for geographical studies, and even for their careful correlation with historical and literary courses, it is in the schools with 'classical' traditions, and a considerable 'classical side' at all events in their upper forms, that geographical teaching most lags and is least organically connected with the humanities.

A Retrospect and a Remedy.

There are of course, here too, historical reasons for this, and on the sound tactical principle of stimulating those with whom one disagrees by explaining that they cannot be expected from their antecedents to be other than they regrettably are, I propose to look in this direction for excuses, and also for a remedy. In difficult country, if a man has taken the wrong road it is safest to avoid short cuts, and bring him back to the point where he went astray. The right road is often obvious to him then.

In the early days of the Renascence the scholars themselves were mainly of Mediterranean origin, or at least had made acquaintance with Mediterranean conditions by pilgrimage to Italian libraries and lecture-rooms. Moreover, as long as Venice and Genoa held the seas, even the Levant was familiar to Western society at large, in a way which became impossible for nearly three centuries, after the evacuation of Rhodes and Famagusta. There was therefore little need for interpreters of the classics to dwell on the physical surroundings of the ancient world, for in essentials they were the same as their own. But when the centres of humanist activity shifted beyond the Alps, and the Turk, in his decline, laid more jealous hold on Greek lands, empirical knowledge of the Near East faded, and classical weather, classical flowers and herbs, and still more those classical customs and institutions, such as seasonal warfare, a national outdoor drama, and democracy itself, which depended on Mediterranean conditions for their realisation, passed, with much else that was incapable of realisation on the Atlantic seaboard, from common knowledge into academic oblivion.

The same thing happened elsewhere. Troubadour songs from a land where the hawthorn really blooms in May, and it is possible for outlaws to disport themselves 'under the greenwood tree' without the rheumatic sequel of our Whit Monday, forged a link between flower and month which centuries of the 'jocund spring' of these islands have failed to break. Or, to take a reverse instance, an occasion

> 'When shepherds watched their flocks by night,
> All seated on the ground,'

is still accepted by many as a credible description of Palestine in December. What meaning, again, does the normal British citizen attach to that graphic time-signal (II Samuel xi. 1): 'And it came to pass, at the return of the year, at the time when kings go out to battle '?—that is how that evening is depicted when David first saw Bathsheba. The pendant picture is Alcman's phrase about spring in early Greece 'when buds grow green

and you cannot eat enough.' Truly the Christian Church had its reasons, down there, when it prescribed fasting in Lent.

It was, then, mainly unavoidable ignorance, imposed by the political situation, that paralysed geographical commentary on ancient history and literature. But this happened, unfortunately, close to the time when the great Dutch scholars of the seventeenth century, and thereafter our own Bentley, gave a new birth to linguistic study, and gave also to 'scholarship' the narrower meaning which it has unluckily retained so long. It happened, unfortunately also, at a moment when the social cleavage which resulted in this country from the Civil War, and still more from the behaviour of the 'Restored' in matters of faith and citizenship, cut English education —I cannot speak for Scottish—into two differently conducted halves. All that side of the national heritage which descended from the culture of Israel remained essentially vernacular, with no bogey of 'compulsory Hebrew' to repel the beginner, until the need to read Hebrew for himself overmastered him from within. This heritage had been, and remained, common to all, though for all alike it was divorced, for the reasons already noted, from its geographical context and background. But, in the transmission of the 'Legacy of Greece' the Renaissance use of popular translations in popular education—the chained copy of North's 'Plutarch' in the village church, alongside the Authorised Version, as you may see it at Bicester to-day—gave place to the strict 'classical education' of the public schools and older universities, initiated in the 'preparatory' schools as they arose; and displaced into the nursery the vernacular discipline of an 'authorised' crib. Formal scholarship became indispensable prerequisite to study of Mediterranean culture; history and geography, as interpreters of the meaning of great literatures, gave place to 'gerund-grinding' and vain 'repetitions,' as you may hear students crooning the Koran in a Moslem university to-day.

It was more than a century before reaction came: and the new renaissance in classical and oriental studies came, like the old, very largely from outside. What the discoverers of America and the outer Oceans were to the men of 1493, the pioneers in physics, chemistry and biology were to the generation of 1793. Herder's *Ideen zur Philosophie der Geschichte der Menschheit* began to appear in 1784; it had been preceded in 1778 by his *Stimmen der Völker in Liedern*, the first regional investigation of popular literature, and in 1782 by *Vom Geist der hebräischen Poesie*, which inaugurates the scientific study of the 'Legacy of Israel.' Wolf's *Prolegomena to Homer* appeared in the next year, 1795; and, speaking on Scottish soil, more especially am I bound to commemorate the debt both of Wolf and of Herder to Percy's *Reliques* and Macpherson's *Ossian*, and as an Englishman, Wolf's obligation to Robert Wood's *Essay on the Original Genius of Homer*, the first study of Greek literature on Greek seas, and of Biblical institutions in a Bedawin tent at Palmyra. How close the beginnings of modern geography lie to this movement in history and literature needs hardly to be illustrated. But Alexander von Humboldt was, like Wolf, a pupil of old Heyne at Göttingen, and close friend of Heyne's son-in-law Georg Forster, the naturalist and chronicler of Captain Cook; and it was in the same Göttingen circle a little later (1814–19) that Karl Ritter matured his *Erdkunde im Verhältnis zur Natur und zur Geschichte des Menschen* (1817–18), followed by his essay on prehistoric ethnology

in 1820 (*Vorhalle europäischer Völkergeschichten vor Herodot*). In the rejuvenation of Prussia it was Hardenberg himself who brought Niebuhr from Copenhagen to the Finance Ministry in 1806, and von Stein who entrusted mainly to him, under the direction of Karl Wilhelm von Humboldt, the reorganisation of classical teaching in the Berlin University; and while von Humboldt called in Wolf from Halle, on the fame of his revolutionary *Prolegomena*, Niebuhr, reserving the recreation of Roman history for himself, called August Boeckh from Heidelberg in 1811 as the scholar best fitted to apply ancient experience to the training of a modern civil service. The response was the *Political Economy of Athens*; and it was Boeckh's greatest discovery, Karl Otfried Müller, whose *Histories of the Greek Peoples and Cities* (of which the first section appeared in 1816) brought the new geography and the new history into partnership. Otfried Müller in his turn inspired Ernst Curtius to his epoch-making monograph on the Peloponnese, which was published in the year of our 'Great Exhibition'; and before this, thanks mainly to George Cornewall Lewis, Niebuhr's *Lectures on Roman History*, Boeckh's *Political Economy of Athens*, and Müller's *Dorians* had been vigorously translated into English, and the new leaven was working briskly already when George Grote was writing his *History of Greece*. Of Curtius' *Peloponnese*, 'I have spent my life,' said Boeckh, in admitting the author to the Berlin Academy in 1853, 'testing and sifting details, the necessary foundation for further research. But you have seen the land itself, the frame to the picture.' And the aged Humboldt wrote 'I have read your first volume line by line. Your survey of the country is a masterpiece of nature painting.'

Well, after seventy years more, the picture begins to be worthy of the frame. Whom will you allow to enjoy it? It is not finished, nor will it ever be. But a man's pupils surely are entitled to a 'private view' of *his* sketches in the studio of ancient geography.

We must start, of course, with things as they are; and if we are not satisfied with things as they are—and I hope I may assume that such dissatisfaction is normal and usual—we must above all things be careful not to make them worse by overloading with 'new' subjects an already congested curriculum. But we are bound, no less, to take every occasion of change in departments adjacent to our own, for some reduction of the customary gaps, perhaps unavoidable altogether, when knowledge is dissected academically into subjects, and courses, and periods of fifty minutes nominal. And let me repeat here what I hinted at the outset, that by ancient geography, as by 'geographical thinking' in general, I do not mean yet another obstacle to the convenient planning of a time-table, but an element in the content of many courses of instruction, and above all a point of view, and a fund of illustrative humanising knowledge and appreciation, on the part of the teacher. The children are all right—that, as teachers, we all know. If we can get the teaching right—which in the first place means getting ourselves, the teachers, right—I do not very much mind what ancient geography, or any other subject, is called, in the syllabus or the time-table. That is why ancient geography is so necessary a part of university equipment; for it is in the universitie that we prepare the teachers.

INCREASING RETURNS AND ECONOMIC PROGRESS.

ADDRESS BY

PROF. ALLYN A. YOUNG,

PRESIDENT OF THE SECTION.

My subject, I fear, may appear alarmingly formidable, but I did not intend it to be so. The words economic progress, taken by themselves, would suggest the pursuit of some philosophy of history, of some way of appraising the results of past and possible future changes in forms of economic organisation and modes of economic activities. But as I have used them, joined to the other half of my title, they are meant merely to dispel apprehensions, by suggesting that I do not propose to discuss any of those alluring but highly technical questions relating to the precise way in which some sort of equilibrium of supply and demand is achieved in the market for the products of industries which can increase their output without increasing their costs proportionately, or to the possible advantages of fostering the development of such industries while putting a handicap upon industries whose output can be increased only at the expense of a more than proportionate increase of costs. I suspect, indeed, that the apparatus which economists have built up for dealing effectively with the range of questions to which I have just referred may stand in the way of a clear view of the more general or elementary aspects of the phenomena of increasing returns, such as I wish to comment upon in this paper.

Consider, for example, Alfred Marshall's fruitful distinction between the internal productive economies which a particular firm is able to secure as the growth of the market permits it to enlarge the scale of its operations and the economies external to the individual firm which show themselves only in changes of the organisation of the industry as a whole. This distinction has been useful in at least two different ways. In the first place it is, or ought to be, a safeguard against the common error of assuming that wherever increasing returns operate there is necessarily an effective tendency towards monopoly. In the second place it simplifies the analysis of the manner in which the prices of commodities produced under conditions of increasing returns are determined. A representative firm within the industry, maintaining its own identity and devoting itself to a given range of activities, is made to be the vehicle or medium through which the economies achieved by the industry as a whole are transmitted to the market and have their effect upon the price of the product.

The view of the nature of the processes of industrial progress which is implied in the distinction between internal and external economies is

necessarily a partial view. Certain aspects of those processes are illuminated, while, for that very reason, certain other aspects, important in relation to other problems, are obscured. This will be clear, I think, if we observe that, although the internal economies of some firms producing, let us say, materials or appliances may figure as the external economies of other firms, not all of the economies which are properly to be called external can be accounted for by adding up the internal economies of all the separate firms. When we look at the internal economies of a particular firm we envisage a condition of comparative stability. Year after year the firm, like its competitors, is manufacturing a particular product or group of products, or is confining itself to certain definite stages in the work of forwarding the products towards their final form. Its operations change in the sense that they are progressively adapted to an increasing output, but they are kept within definitely circumscribed bounds. Out beyond, in that obscurer field from which it derives its external economies, changes of another order are occurring. New products are appearing, firms are assuming new tasks, and new industries are coming into being. In short, change in this external field is qualitative as well as quantitative. No analysis of the forces making for economic equilibrium, forces which we might say are tangential at any moment of time, will serve to illumine this field, for movements away from equilibrium, departures from previous trends, are characteristic of it. Not much is to be gained by probing into it to see how increasing returns show themselves in the costs of individual firms and in the prices at which they offer their products.

Instead, we have to go back to a simpler and more inclusive view, such as some of the older economists took when they contrasted the increasing returns which they thought were characteristic of manufacturing industry taken as a whole with the diminishing returns which they thought were dominant in agriculture because of an increasingly unfavourable proportioning of labour and land. Most of them were disappointingly vague with respect to the origins and the precise nature of the 'improvements' which they counted upon to retard somewhat the operation of the tendency towards diminishing returns in agriculture and to secure a progressively more effective use of labour in manufactures. Their opinions appear to have rested partly upon an empirical generalisation. Improvements had been made, they were still being made, and it might be assumed that they would continue to be made. If they had looked back they would have seen that there were centuries during which there were few significant changes in either agricultural or industrial methods. But they were living in an age when men had turned their faces in a new direction and when economic progress was not only consciously sought but seemed in some way to grow out of the nature of things. Improvements, then, were not something to be explained. They were natural phenomena, like the precession of the equinoxes.

There were certain important exceptions, however, to this incurious attitude towards what might seem to be one of the most important of all economic problems. Senior's positive doctrine is well known, and there were others who made note of the circumstance that with the growth of population and of markets new opportunities for the division of labour appear and new advantages attach to it. In this way, and in this way

only, were the generally commonplace things which they said about 'improvements' related to anything which could properly be called a doctrine of increasing returns. They added nothing to Adam Smith's famous theorem that the division of labour depends upon the extent of the market. That theorem, I have always thought, is one of the most illuminating and fruitful generalisations which can be found anywhere in the whole literature of economics. In fact, as I am bound to confess, I am taking it as the text of this paper, in much the way that some minor composer borrows a theme from one of the masters and adds certain developments or variations of his own. To-day, of course, we mean by the division of labour something much broader in scope than that splitting up of occupations and development of specialised crafts which Adam Smith mostly had in mind. No one, so far as I know, has tried to enumerate all of the different aspects of the division of labour, and I do not propose to undertake that task. I shall deal with two related aspects only: the growth of indirect or roundabout methods of production and the division of labour among industries.

It appears to be generally agreed that Adam Smith, when he suggested that the division of labour leads to inventions because workmen engaged in specialised routine operations come to see better ways of accomplishing the same results, missed the main point. The important thing, of course, is that with the division of labour a group of complex processes is transformed into a succession of simpler processes, some of which, at least, lend themselves to the use of machinery. In the use of machinery and the adoption of indirect processes there is a further division of labour, the economies of which are again limited by the extent of the market. It would be wasteful to make a hammer to drive a single nail; it would be better to use whatever awkward implement lies conveniently at hand. It would be wasteful to furnish a factory with an elaborate equipment of specially constructed jigs, gauges, lathes, drills, presses and conveyors to build a hundred automobiles; it would be better to rely mostly upon tools and machines of standard types, so as to make a relatively larger use of directly-applied and a relatively smaller use of indirectly-applied labour. Mr. Ford's methods would be absurdly uneconomical if his output were very small, and would be unprofitable even if his output were what many other manufacturers of automobiles would call large.

Then, of course, there are economies of what might be called a secondary order. How far it pays to go in equipping factories with special appliances for making hammers or for constructing specialised machinery for use in making different parts of automobiles depends again upon how many nails are to be driven and how many automobiles can be sold. In some instances, I suppose, these secondary economies, though real, have only a secondary importance. The derived demands for many types of specialised production appliances are inelastic over a fairly large range. If the benefits and the costs of using such appliances are spread over a relatively large volume of final products, their technical effectiveness is a larger factor in determining whether it is profitable to use them than any difference which producing them on a large or a small scale would commonly make in their costs. In other instances the demand for

productive appliances is more elastic, and beyond a certain level of costs demand may fail completely. In such circumstances secondary economies may become highly important.

Doubtless, much of what I have said has been familiar and even elementary. I shall venture, nevertheless, to put further stress upon two points, which may be among those which have a familiar ring, but which appear sometimes to be in danger of being forgotten. (Otherwise, economists of standing could not have suggested that increasing returns may be altogether illusory, or have maintained that where they are present they must lead to monopoly.) The first point is that the principal economies which manifest themselves in increasing returns are the economies of capitalistic or roundabout methods of production. These economies, again, are largely identical with the economies of the division of labour in its most important modern forms. In fact, these economies lie under our eyes, but we may miss them if we try to make of *large-scale* production (in the sense of production by large firms or large industries), as contrasted with *large* production, any more than an incident in the general process by which increasing returns are secured and if accordingly we look too much at the individual firm or even, as I shall suggest presently, at the individual industry.

The second point is that the economies of roundabout methods, even more than the economies of other forms of the division of labour, depend upon the extent of the market—and that, of course, is why we discuss them under the head of increasing returns. It would hardly be necessary to stress this point, if it were not that the economies of large-scale operations and of 'mass-production' are often referred to as though they could be had for the taking, by means of a 'rational' reorganisation of industry. Now I grant that at any given time routine and inertia play a very large part in the organisation and conduct of industrial operations. Real leadership is no more common in industrial than in other pursuits. New catch-words or slogans like mass-production and rationalisation may operate as stimuli; they may rouse men from routine and lead them to scrutinise again the organisation and processes of industry and to try to discover particular ways in which they can be bettered. For example, no one can doubt that there are genuine economies to be achieved in the way of 'simplification and standardisation,' or that the securing of these economies requires that certain deeply rooted competitive wastes be extirpated. This last requires a definite concerted effort—precisely the kind of thing which ordinary competitive motives are often powerless to effect, but which might come more easily as the response to the dissemination of a new idea.

There is a danger, however, that we shall expect too much from these 'rational' industrial reforms. Pressed beyond a certain point they become the reverse of rational. I have naturally been interested in British opinions respecting the reasons for the relatively high productivity (per labourer or per hour of labour) of representative American industries. The error of those who suggest that the explanation is to be found in the relatively high wages which prevail in America is not that they confuse cause and effect, but that they hold that what are really only two aspects of a single situation are, the one cause, and the other effect. Those who

hold that American industry is managed better, that its leaders study its problems more intelligently and plan more courageously and more wisely can cite no facts in support of their opinion save the differences in the results achieved. Allowing for the circumstance that British industry, as a whole, has proved to be rather badly adjusted to the new post-war economic situation, I know of no facts which prove or even indicate that British industry, seen against the background of its own problems and its own possibilities, is less efficiently organised or less ably directed than American industry or the industry of any other country.

Sometimes the fact that the average American labourer works with the help of a larger supply of power-driven labour-saving machinery than the labourer of other countries is cited as evidence of the superior intelligence of the average American employer. But this will not do, for, as every economist knows, the greater the degree in which labour is productive or scarce—the words have the same meaning—the greater is the relative economy of using it in such indirect or roundabout ways as are technically advantageous, even though such procedure calls for larger advances of capital than simpler methods do.

It is encouraging to find that a fairly large number of commentators upon the volume of the American industrial product and the scale of American industrial organisation have come to surmise that the extent of the American domestic market, unimpeded by tariff barriers, may have something to do with the matter. This opinion seems even to be forced upon thoughtful observers by the general character of the facts, whether or no the observers think in terms of the economists' conception of increasing returns. In certain industries, although by no means in all, productive methods are economical and profitable in America which would not be profitable elsewhere. The importance of coal and iron and other natural resources needs no comment. Taking a country's economic endowment as given, however, the most important single factor in determining the effectiveness of its industry appears to be the size of the market. But just what constitutes a large market? Not area or population alone, but buying power, the capacity to absorb a large annual output of goods. This trite observation, however, at once suggests another equally trite, namely, that capacity to buy depends upon capacity to produce. In an inclusive view, considering the market not as an outlet for the products of a particular industry, and therefore external to that industry, but as the outlet for goods in general, the size of the market is determined and defined by the volume of production. If this statement needs any qualification, it is that the conception of a market in this inclusive sense—an aggregate of productive activities, tied together by trade—carries with it the notion that there must be some sort of balance, that different productive activities must be proportioned one to another.

Modified, then, in the light of this broader conception of the market, Adam Smith's dictum amounts to the theorem that the division of labour depends in large part upon the division of labour. This is more than mere tautology. It means, if I read its significance rightly, that the counter forces which are continually defeating the forces which make for economic equilibrium are more pervasive and more deeply rooted in the constitution of the modern economic system than we commonly

realise. Not only new or adventitious elements, coming in from the outside, but elements which are permanent characteristics of the ways in which goods are produced make continuously for change. Every important advance in the organisation of production, regardless of whether it is based upon anything which, in a narrow or technical sense, would be called a new 'invention,' or involves a fresh application of the fruits of scientific progress to industry, alters the conditions of industrial activity and initiates responses elsewhere in the industrial structure which in turn have a further unsettling effect. Thus change becomes progressive and propagates itself in a cumulative way.

The apparatus which economists have built up for the analysis of supply and demand in their relations to prices does not seem to be particularly helpful for the purposes of an inquiry into these broader aspects of increasing returns. In fact, as I have already suggested, reliance upon it may divert attention to incidental or partial aspects of a process which ought to be seen as a whole. If, nevertheless, one insists upon seeing just how far one can get into the problem by using the formulas of supply and demand, the simplest way, I suppose, is to begin by inquiring into the operations of reciprocal demand when all of the commodities exchanged are produced competitively under conditions of increasing returns and when the demand for each commodity is elastic, in the special sense that a small increase in the supply of any one commodity will be attended by an increase in the amounts of other commodities which can be had in exchange for it.[1] Under such conditions an increase in the supply of one commodity *is* an increase in the demand for other commodities, and it must be supposed that every increase in demand will evoke an increase in supply. The rate at which any one industry grows is conditioned by the rate at which other industries grow, but since the elasticities of demand and of supply will differ for different products, some industries will grow faster than others. Even with a stationary population and in the absence of new discoveries[2] in pure or applied science there are no limits to the process of expansion except the limits beyond which demand is not elastic and returns do not increase.

If, under these hypothetical conditions, progress were unimpeded and frictionless, if it were not dependent in part upon a process of trial and error, if the organisation of industry were always such as, in relation to the immediate situation, is most economical, the realising of increasing returns might be progressive and continuous, although, for technical reasons, it could not always proceed at an even rate. But it would remain a process requiring time. An industrial dictator, with foresight and knowledge, could hasten the pace somewhat, but he could not achieve an Aladdin-like transformation of a country's industry, so as to reap the

[1] This condition is merely that dy/dx and dx/dy are both positive, where x and y are the amounts of any two commodities exchanged. If the circumstance that commodity a is produced under conditions of increasing returns is taken into account as a factor in the elasticity of demand for b in terms of a, elasticity of demand and elasticity of supply may be looked upon as different ways of expressing a single functional relation. The condition as stated is more rigorous than need be.

[2] As contrasted with such new ways of organising production and such new 'inventions' as are merely adaptations of known ways of doing things, made practicable and economical by an enlarged scale of production.

fruits of a half-century's ordinary progress in a few years. The obstacles are of two sorts. First, the human material which has to be used is resistant to change. New trades have to be learnt and new habits have to be acquired. There has to be a new geographical distribution of the population and established communal groups have to be broken up. Second, the accumulation of the necessary capital takes time, even though the process of accumulation is largely one of turning part of an increasing product into forms which will serve in securing a further increase of product. An acceleration of the rate of accumulation encounters increasing costs, into which both technical and psychological elements enter. One who likes to conceive of all economic processes in terms of tendencies towards an equilibrium might even maintain that increasing returns, so far as they depend upon the economies of indirect methods of production and the size of the market, are offset and negated by their costs, and that under such simplified conditions as I have dealt with the realising of increasing returns would be spread through time in such a way as to secure an equilibrium of costs and advantages. This would amount to saying that no real economic progress could come through the operation of forces engendered *within* the economic system—a conclusion repugnant to common sense. To deal with this point thoroughly would take us too far afield. I shall merely observe, first, that the appropriate conception is that of a *moving* equilibrium, and second, that the costs which (under increasing returns) grow less rapidly than the product are not the 'costs' which figure in an 'equilibrium of costs and advantages.'

Moving away from these abstract considerations, so as to get closer to the complications of the real situation, account has to be taken, first, of various kinds of obstacles. The demand for some products is inelastic, or, with an increasing supply, soon becomes so. The producers of such commodities, however, often share in the advantages of the increase of the general scale of production in related industries, and so far as they do productive resources are released for other uses. Then there are natural scarcities, limitations or inelasticities of supply, such as effectively block the way to the securing of any important economies in the production of some commodities and which impair the effectiveness of the economies secured in the production of other commodities. In most fields, moreover, progress is not and cannot be continuous. The next important step forward is often initially costly, and cannot be taken until a certain quantum of prospective advantages has accumulated.

On the other side of the account are various factors which reinforce the influences which make for increasing returns. The discovery of new natural resources and of new uses for them and the growth of scientific knowledge are probably the most potent of such factors. The causal connections between the growth of industry and the progress of science run in both directions, but on which side the preponderant influence lies no one can say. At any rate, out of better knowledge of the materials and forces upon which men can lay their hands there come both new ways of producing familiar commodities and new products, and these last have a presumptive claim to be regarded as embodying more economical uses of productive resources than the uses which they displace. Some weight has to be given also to the way in which, with the advance of the scientific

spirit, a new kind of interest—which might be described as a scientific interest conditioned by an economic interest—is beginning to infiltrate into industry. It is a point of controversy, but I venture to maintain that under most circumstances, though not in all, and short of the point at which diminishing returns, in the Ricardian sense, become important in the aggregate, the growth of population still has to be counted a factor making for a larger per capita product—although even that cautious statement needs to be interpreted and qualified. But just as there may be population growth with no increase of the average per capita product, so also, as I have tried to suggest, markets may grow and increasing returns may be secured while the population remains stationary.

It is dangerous to assign to any single factor the leading role in that continuing economic revolution which has taken the modern world so far away from the world of a few hundred years ago. But is there any other factor which has a better claim to that role than the persisting search for markets? No other hypothesis so well unites economic history and economic theory. The Industrial Revolution of the eighteenth century has come to be generally regarded, not as a cataclysm brought about by certain inspired improvements in industrial technique, but as a series of changes related in an orderly way to prior changes in industrial organisation and to the enlargement of markets. It is sometimes said, however, that while in the Middle Ages and in the early modern period industry was the servant of commerce, since the rise of 'industrial capitalism' the relation has been reversed, commerce being now merely an agent of industry. If this means that the finding of markets is one of the tasks of modern industry it is true. If it means that industry imposes its will upon the market, that whereas formerly the things which were produced were the things which could be sold, now the things which have to be sold are the things that are produced, it is not true.

The great change, I imagine, is in the new importance which the *potential market* has in the planning and management of large industries. The difference between the cost per unit of output in an industry or in an individual plant properly adapted to a given volume of output and in an industry or plant equally well adapted to an output five times as large is often much greater than one would infer from looking merely at the economies which may accrue as an existing establishment gradually extends the scale of its operations. Potential demand, then, in the planning of industrial undertakings, has to be balanced against potential economies, elasticity of demand against decreasing costs. The search for markets is not a matter of disposing of a 'surplus product,' in the Marxian sense, but of finding an outlet for a potential product. Nor is it wholly a matter of multiplying profits by multiplying sales; it is partly a matter of augmenting profits by reducing costs.

Although the initial displacement may be considerable and the repercussions upon particular industries unfavourable, the enlarging of the market for any one commodity, produced under conditions of increasing returns, generally has the net effect, as I have tried to show, of enlarging the market for other commodities. The business man's mercantilistic emphasis upon markets may have a sounder basis than the economist who thinks mostly in terms of economic statics is prone to

admit. How far 'selling expenses,' for example, are to be counted sheer economic waste depends upon their effects upon the aggregate product of industry, as distinguished from their effects upon the fortunes of particular undertakings.

Increasing returns are often spoken of as though they were attached always to the growth of 'industries,' and I have not tried to avoid that way of speaking of them, although I think that it may be a misleading way. The point which I have in mind is something more than a quibble about the proper definition of an industry, for it involves a particular thesis with respect to the way in which increasing returns are reflected in changes in the organisation of industrial activities. Much has been said about industrial integration as a concomitant or a natural result of an increasing industrial output. It obviously is, under particular conditions, though I know of no satisfactory statement of just what those particular conditions are. But the opposed process, industrial differentiation, has been and remains the type of change characteristically associated with the growth of production. Notable as has been the increase in the complexity of the apparatus of living, as shown by the increase in the variety of goods offered in consumers' markets, the increase in the diversification of intermediate products and of industries manufacturing special products or groups of products has gone even further.

The successors of the early printers, it has often been observed, are not only the printers of to-day, with their own specialised establishments, but also the producers of wood pulp, of various kinds of paper, of inks and their different ingredients, of type-metal and of type, the group of industries concerned with the technical parts of the producing of illustrations, and the manufacturers of specialised tools and machines for use in printing and in these various auxiliary industries. The list could be extended, both by enumerating other industries which are directly ancillary to the present printing trades and by going back to industries which, while supplying the industries which supply the printing trades, also supply other industries, concerned with preliminary stages in the making of final products other than printed books and newspapers. I do not think that the printing trades are an exceptional instance, but I shall not give other examples, for I do not want this paper to be too much like a primer of descriptive economics or an index to the reports of a census of production. It is sufficiently obvious, anyhow, that over a large part of the field of industry an increasingly intricate nexus of specialised undertakings has inserted itself between the producer of raw materials and the consumer of the final product.

With the extension of the division of labour among industries the representative firm, like the industry of which it is a part, loses its identity. Its internal economies dissolve into the internal and external economies of the more highly specialised undertakings which are its successors, and are supplemented by new economies. In so far as it is an adjustment to a new situation created by the growth of the final products of industry the division of labour among industries is a vehicle of increasing returns. It is more than a change of form incidental to the full securing of the advantages of capitalistic methods of production—although it is largely that—for it has some advantages of its own which are independent of

changes in productive technique. For example, it permits of a higher degree of specialisation in management, and the advantages of such specialisation are doubtless often real, though they may easily be given too much weight. Again, it lends itself to a better geographical distribution of industrial operations, and this advantage is unquestionably both real and important. Nearness to the source of supply of a particular raw material or to cheap power counts for most in one part of a series of industrial processes, nearness to other industries or to cheap transport in another part, and nearness to a larger centre of population in yet another. A better *combination* of advantages of location, with a smaller element of compromise, can be had by the more specialised industries. But the largest advantage secured by the division of labour among industries is the fuller realising of the economies of capitalistic or roundabout methods of production. This should be sufficiently obvious if we assume, as we must, that in most industries there are effective, though elastic, limits to the economical size of the individual firm. The output of the individual firm is generally a relatively small proportion of the aggregate output of an industry. The degree in which it can secure economies by making its own operations more roundabout is limited. But certain roundabout methods are fairly sure to become feasible and economical when their advantages can be spread over the output of the whole industry. These potential economies, then, are segregated and achieved by the operations of specialised undertakings which, taken together, constitute a new industry. It might conceivably be maintained that the *scale* upon which the firms in the new industry are able to operate is the secret of their ability to realise economies for industry as a whole, while presumably making profits for themselves. This is true in a way, but misleading. The scale of their operations (which is only incidentally or under special conditions a matter of the size of the individual firm) merely reflects the size of the market for the final products of the industry or industries to whose operations their own are ancillary. And the principal advantage of large-scale operation at this stage is that it again makes methods economical which would be uneconomical if their benefits could not be diffused over a large final product.

In recapitulation of these variations on a theme from Adam Smith there are three points to be stressed. First, the mechanism of increasing returns is not to be discerned adequately by observing the effects of variations in the size of an individual firm or of a particular industry, for the progressive division and specialisation of industries is an essential part of the process by which increasing returns are realised. What is required is that industrial operations be seen as an interrelated whole. Second, the securing of increasing returns depends upon the progressive division of labour, and the principal economies of the division of labour, in its modern forms, are the economies which are to be had by using labour in roundabout or indirect ways. Third, the division of labour depends upon the extent of the market, but the extent of the market also depends upon the division of labour. In this circumstance lies the possibility of economic progress, apart from the progress which comes as a result of the new knowledge which men are able to gain, whether in the pursuit of their economic or of their non-economic interests.

SECTION G.—ENGINEERING.

THE INFLUENCE OF ENGINEERING ON CIVILIZATION.

ADDRESS BY

SIR WILLIAM ELLIS, G.B.E., D.Eng.,

PRESIDENT OF THE SECTION.

In choosing the subject for my address I had to decide whether to devote my attention to some branch of engineering in which I have been actively engaged during my working life, alluding specially to some of the technical problems involved, or to treat of engineering in a less technical manner so as to interest any hearers or readers of this address who may not themselves be actively engaged in the engineering profession. Knowing that the Engineering Section would be addressed on technical subjects by very distinguished engineers, I have decided to devote my address to speaking of the very extensive part which engineering in its many branches has taken, and is still taking, in connexion with the amenities which are associated so closely with our domestic life, and indeed, our happiness. I shall hope in the course of my address to deal in some detail with the fact that each branch of engineering has added its quota to the comfort of our lives, and I think it may be claimed that no other profession has so direct an association with our modern civilization. The enormous increase in population during the nineteenth century, coupled with the segregation of that population in industrial centres, arising out of the extraordinarily rapid development of industry in this and other countries during that period, has introduced new problems in connexion with health and transport, and it has been the task of engineering in its many branches to deal with these problems. It must be admitted that the great advances made in the knowledge of both medicine and surgery have played a very noble part in connexion with improvements we all welcome in the health of the population, and in speaking of the part which engineering has taken in connexion with public health I have no wish to lessen in any way what we all admire and respect, namely, the wonderful work of the medical profession in applying for our benefit the constantly advancing scientific and practical knowledge.

In the early part of the nineteenth century main roads did not exist in this country to any great extent, and these roads were in a very inferior condition. Pack horse transport was still in vogue, and up to 1850 a well-organised system of mail coaches was the principal means of passenger transport.

The introduction of railways and of steamers during the first half of that century led the way to an enormously increased demand for coal,

iron and steel, and as the inventions of Sir Henry Bessemer and Sir William Siemens for making steel were developed, the necessity was evident to engineers and chemists for training schools to deal with the physical and technical problems involved in engineering and metallurgy, so as to arrive at a far greater accuracy, both in design and construction, than had hitherto been considered necessary or possible. I find on reading the history of those early pioneers, both in engineering and metallurgy, that they had to meet conditions similar to those which exist to-day, that is to say, they had to force their ideas on to a rather unwilling public in order to get them introduced, and in many cases they did not reap the reward of their enterprise. Boulton and Watt had a desperate struggle for their existence. Stephenson had great difficulty in even getting his engine tried amongst those competing for the Liverpool to Manchester railway, and yet was the only successful survivor of the trials. To-day the fate of the inventor is little less hard. In many cases he finds his invention has been anticipated, and in others there is great unwillingness on the part of engineers and metallurgists to adopt the ideas because of the risk involved financially in developing the processes.

We have to admit, however, that the progress of industry depends very largely on the enterprise of deep-thinking men who are ahead of the times in their ideas. I may quote Dr. Clifton Sorby, F.R.S., as such an instance. He introduced by his researches the microscopy of steel, and yet it was many years before this became a recognised method of gauging the quality of all classes of steel. Another great inventor, whom we all respect and are delighted to have still in active work, is Sir Charles Parsons. I look back many years to the early eighties when Sir Charles put in years of research work in connexion with high speed engines before he successfully produced the steam turbine. Since that time he has devoted a large portion of his life to developing improvements both in the design of the turbine and the machinery for producing it, which have ultimately brought about its world renown, and his eminence in the engineering world was suitably recognised two years ago by the award of the Kelvin Gold Medal.

The technical societies in this country in the latter part of the last century realised that special attention would have to be devoted to an education which would combine a practical knowledge of engineering with a course of technical education of a high level. This was also associated with a preliminary examination to ensure that their students should have a sufficient grounding in general knowledge to enable them to apply themselves with success to the more intricate technical problems incident to their profession. This action on the part of these institutions has been fully rewarded by bringing into existence a body of highly trained engineers with special knowledge of the different branches of engineering, and, therefore, well able to lead our profession forward in the great developments which are still taking place in all branches of engineering.

Although in this address it would be out of place for me to discuss education in detail, I cannot help feeling that the ground to be covered in engineering education is now so great that the universities will do well to apply education in general engineering problems for the first two years of a university course, and allow an honours degree to be taken in one or

other of the special branches of engineering. I would urge that with the very short terms existing at our universities, in some cases only three terms of eight weeks each, it is unreasonable to expect a student to take an honours degree in three years if this covers all branches of engineering science. The alternative now being considered of meeting the difficulty by taking four years for an honours degree is, I think, open to grave objection, as it is delaying too long the date at which a young engineer is available to take up his first professional appointment and in fact become an earner.

Coming back to my original subject, can we say which branch of engineering has most directly been associated with modern civilization? I do not find that any one branch can claim the premier position. It depends, of course, very much on what we regard as the greatest essentials in life, and I presume we must admit that the greatest happiness of the greatest number must be taken as the true gauge. In this case some of the luxuries and comforts of modern travel do not hold a primary position, much as we appreciate them. Such questions as purity and sufficiency of water supply for large cities coupled with a scientific system of drainage, are the first essentials of health and comfort, especially in areas with large populations.

I will now turn to the different branches of engineering and illustrate as far as I can the benefits which these branches of engineering have introduced into the civilization of our present age. In doing so I would refer to the definition of engineering given in the Royal Charter of the Institution of Civil Engineers on its incorporation in 1828. The centenary of the institution has just been celebrated, and all engineers must be grateful to the Principal of Edinburgh University, Sir Alfred Ewing, for the carefully thought out review of engineering progress in the last century, which formed the subject of the James Forrest address at the centenary meeting in June. The charter describes engineering as 'a mechanical science dealing with the art of directing the great sources of power in nature for the use and convenience of man.' The term 'civil engineering' is a comprehensive one embracing all branches of the profession, other than military engineering, but I propose to apply the words 'civil engineering' in this address as dealing specially with drainage and irrigation works, harbours, docks, reservoirs, &c., dealing with railways under the heading of transport.

The various branches of engineering I propose to allude to shortly in detail are as follows :—

Civil Engineering, as defined above.
Transport.
Shipbuilding, including Marine Engineering.
Mechanical Engineering.
Mining Engineering.
Electrical Engineering.

Civil Engineering.

The point which appears to me to stand out prominently in this branch of the profession is the fact that the structures to be dealt with are in many cases of an enormously costly nature, and have to be carried

out with such careful study and comprehension of the varying problems to be dealt with so as to ensure permanent efficiency and safety in the future.

The great reservoirs and harbours of the world may be regarded as the cathedrals of engineering. The varying natural problems to be dealt with involve a very high level of technical education. In the construction of reservoirs, docks and harbours, a considerable knowledge of geology is essential, and in harbour construction the varying effects of tides which have to be studied minutely, have an important influence on the work to be undertaken. Throughout the world will be found monuments to the skill of the civil engineer and the very existence of the population in our large cities in health and comfort is the result of his work, for without an ample and reliable supply of water of good quality, both for personal and industrial use, and an efficient drainage control, our death-rate would indeed be very different from what it is. If we turn for a moment either to India with its great barrage enterprise, or Egypt, with the noble Assouan and Sennaar dams, truly outstanding works of the civil engineer, we find the prosperity of these countries largely resulting from the magnificent irrigation works which have been carried out there. Special development of produce growing in many countries is only being limited by the fact that insufficient irrigation works have so far been carried out. New Mexico and Arizona are two great provinces with potentially fertile land available for agricultural development, but they are so short of water that irrigation is an absolute necessity.

The large increase in tonnage of ocean-going vessels has resulted in the necessity for larger docks and harbour basins, and the development of railways all over the world, many of them in difficult mountainous countries, has given the civil engineer a great opportunity in designing bridges for carrying this heavy traffic. Many of my audience will appreciate the magnitude of the new bridge over Sydney Harbour now being constructed by British engineers, and the Forth Bridge still holds its own as a masterpiece of British engineering skill and the construction was in the hands of a Scotch firm well known in Glasgow. The new high-level bridge at Newcastle and the new Mersey tunnel are, I suppose, the most interesting civil engineering works at present in progress of construction in this country, in addition to the considerable dock extensions now proceeding at Southampton, whilst in Canada a very noble bridge is now being thrown across the St. Lawrence River at Montreal.

Transport.

It may truthfully be said that the development of the potential wealth of any country depends mainly on the means of transport, both personal and industrial. I would allude especially to the great corn-growing countries where the home consumption bears only a small relation to the possible production. The knowledge that there is efficient transport both by rail and for export by sea is the greatest incentive to the farmers to spend money in extensive cultivation with the certainty of a ready market for such production. Without mentioning any countries we probably have instances in our minds where inefficiency of transport facilities is

absolutely blocking the progress of internal wealth in those countries. On the other hand, where railways are efficient and harbours well equipped with shipping facilities, we find consequent prosperity.

The comparison of travel to-day, both by land and sea, with my early journeys in Europe nearly fifty years ago emphasises in my mind how much we are indebted to the engineer, in the way of personal safety and comfort and also prompt delivery of our products. A journey in the Balkans in the winter of 1881 when sleeping cars and restaurant cars were almost unknown, and when the largest vessel sailing from Mediterranean ports was in the neighbourhood of 4,000 tons, compares very unfavourably in speed and personal comfort with the facilities which are available to-day. The comfort and safety of modern travel is to my mind one of the glories of modern civilization. The 40,000 to 50,000 tons Atlantic liner, embracing as it does almost every class of engineering skill, is not only an example of artistic beauty, but is one of the finest instances of human power combating the forces of nature. To be on one of these vessels driving into a gale at twenty knots is an experience never to be forgotten, and we are glad to realize what a large share the shipbuilding firms of Glasgow have had in the development of these large Atlantic liners.

Railway transport has also made great progress in all measures affecting personal safety and the efficient carrying of our various products. The railway engineers have every reason to be proud of their management of the complex organisation represented by the great railway systems all over the world. We are personally much safer travelling in an express train than we are crossing the streets of a great city, and I think we may justly be satisfied by the fact that in no country do the railways afford more comfortable or more rapid travelling facilities than in our own. The railway engineer has still some very interesting problems to face. Heavier and more powerful locomotives are the natural outcome of the demand for heavier freight trains. The civil engineer of a railway company cannot deal with this problem without strengthening bridges and improving the condition of the permanent way. All these developments involve large capital expenditure, which it is not convenient for many railway companies to undertake at the present time.

The question of the railway companies developing motor services to meet the competition of road transport has been the subject of legislation during the present year. I think the public acquiesce generally in the feeling that as the railway companies pay such a large proportion of the rates of the districts through which they have travelling facilities, it is only right they should develop road transport in connexion with their traffic in view of the serious competition which they have to face. Transport by road has undoubtedly been very much facilitated by the large sums which the Ministry of Transport has had available for the purpose of remaking and generally improving our main roads, and careful study has been devoted of late years to the selection of suitable materials for this purpose. Consequently in the last ten years there has been an immense improvement in the quality and design of our main roads, more so than in any previous decade.

It appears to me that one question which has hardly been touched to any extent at present is the desirability of increasing very largely the

number of by-pass roads to divert heavy traffic from passing through large towns, and even villages, which are now suffering severely from congestion of traffic in their altogether too narrow thoroughfares.

On looking back a few years to the old system of horse-drawn tramways, we must surely be grateful for the benefit accruing to many thousands of our working population arising out of the introduction of electric tramways, enabling them to live in many cases in much healthier surroundings.

Naval Architecture.

This comprises shipbuilding and marine engineering and represents a very important part of my subject, dealing, as it does, with the transport by sea and lakes of food and materials, and with the comfort and safety of the many thousands of passengers travelling to and from this country. The wooden vessel in the early part of last century held its own very stubbornly against the introduction of iron or steel vessels, and the mechanically propelled vessel had to fight very hard to oust the very efficient sailing vessels which were then carrying the trade of the world. I imagine that some of my audience with artistic tastes will not be willing to admit that the beauty of the present type of mechanically propelled vessel is comparable with the picturesque five- and six-mast sailing vessels which we used to see in our earlier days. This country has undoubtedly been the pioneer in the building of large warships and passenger liners, also in the development of the very large horse-power therefor. The considerable increase in the tonnage of ships brought with it the necessity for a corresponding increase in the mechanical appliances in connexion with their construction. The trial runs carried out before a new ship is taken over by her owners are a severe test of the excellence of workmanship. They are a necessary test to ensure that long voyages of five to six weeks with machinery running continuously at nearly full power can be undertaken without fear of trouble arising from heated bearings or other causes. A new ship may be exposed to such rough weather on her first voyage that unless her plating and riveting are carried out in a first-rate manner, she may arrive in her first port in a damaged condition. Some of us still remember during the war how new ships, built in other countries, were seriously damaged owing to the workmanship not being of a sufficiently good character. The handling of thick plates of large surfaces and the riveting of them satisfactorily to the stanchions still remains a laborious and trying piece of work for those engaged upon it, although mechanical means exist to some extent. Glasgow has taken a leading part providing men who in all weathers and under conditions rendered difficult by the magnitude of modern vessels, maintain the high level of efficiency which is represented in the manufacture of these large hulls. The vessels of the greatest tonnage built on the Clyde have been the *Aquitania* (46,000 tons) and the *Lusitania* (32,500 tons). Other large vessels built in the British Isles have been the *Olympic* (46,439 tons) and the *Mauretania* (30,696 tons). Since the war there has been a lull in the building of liners of large tonnage and horse-power caused, no doubt, by financial considerations, but it is gratifying to know that two large shipowning companies are at the present time contemplating building vessels up to 1,000 feet in length with a speed of over twenty knots.

Shipbuilding is especially interesting inasmuch as it combines in one structure the varied efforts of almost every class of artisan dealing with both iron and steel and cabinet-making and woodworking generally, in addition, of course, to the large and varied amount of mechanical engineering. In marine engineering the last fifty years have, indeed, a most interesting record of progress, and in very early years such firms as Humphreys Tennant, Maudslay, Son & Field, and other firms no longer in existence, introduced a measure of precision into mechanical engineering probably not then existing in any other branch of the industry. High and low pressure triple expansion engines held their own for a considerable period, and it was, I suppose, the interesting trials of the *Turbinia* which brought about the first change from this method. It is an interesting fact that our fellow-member, Sir Charles Parsons, to whom I have already alluded, should live to see such successful development of his patent, and a recent paper read by him and his co-workers describes in a very interesting manner the gradual developments and changes in design in turbines up to the present time. Such developments range from the *Turbinia*, which had a displacement of 44½ tons with 2,100 h.p., to the battle cruiser *Hood* of 41,200 tons and over 150,000 h.p.

The introduction of geared turbines, so as to arrive at relatively efficient speed as between engine revolutions and propeller revolutions, has brought about valuable economies and helped the turbine principle to maintain its reputation. The development of internal combustion engines for marine purposes has made great strides in recent years. Various types of these engines are already in active service, and a horse-power of 36,000 on four propellers has already been achieved with efficiency; probably the limit has not yet been reached. The use of oil instead of coal on board ship, especially for passenger purposes, represents many advantages, and anyone who has visited the stokehold of a large passenger liner with the hundreds of men stoking with coal must realise the immense advantage, both physical and otherwise, which results from oil burning directly on the boilers. All inconvenience caused by dust in re-coaling is avoided, and the boiler tenting is carried out by young mechanical engineers, doing away with all the labour required by coal burning. In a vessel of large tonnage the saving in wages and maintenance of several hundreds of stokers represents an enormous economy in many directions. The question of larger horse-power and/or electrically driven ships is one of the problems which marine engineers are at present turning their minds to.

A new development which is now being introduced is the use of considerably higher steam pressures in boilers. The first application of this was the *King George V.*, a boat built last year on the Clyde, and our section has been favoured with a paper from Mr. Harold Yarrow dealing with some of the problems which have arisen in introducing high pressures. As you will have gathered from his paper, these problems are not solely those of the engineer who has to build the boilers. They are closely associated with steel and metallurgical questions incident to the special manufacture of parts of the boilers owing to the much greater strength required. Many of my audience, no doubt, have been interested in the valuable information we have received from the paper in question.

The defence of our country depends very largely on the efficiency of our warships, and it is impossible to speak too highly of the wonderful reliability shown by the vessels of our navy during the late war, thanks to the efficient engineering service in our navy, and the determination of the various builders in this country to produce vessels representing the highest standards of engineering efficiency. Our country, I hope, realises how much we owe to the engineering branch of the navy for the well-proved efficiency and courage of its officers and men of all ranks in the late war. I believe that no vessel of our enormous fleet failed in action owing to breakdown of machinery, and the conditions under which the engineering staff find themselves in active warfare must be a severe strain on their courage. The response to the sudden call on the two battle cruisers, which had already been on active service for a considerable time, to make the voyage at full speed to the Falkland Islands to engage the German Fleet, represented an engineering feat of a very high order.

In the mercantile marine we have great cause for thankfulness in the developments which have taken place, resulting in a very much greater comfort at sea. These efforts are naturally limited by the sizes of the harbours between which the vessels have to trade, but when we come to ocean liners the study which naval architecture has given to the production of these great vessels has resulted in our being able to visit different parts of the world with a comfort which is equal to that provided by the best hotels in any of our great cities. Shipbuilding and marine engineering have indeed taken a noble part in assisting the march of civilization and adding to our comforts in every possible way.

I wrote this part of my address on the voyage to New York on the 46,000-tons liner *Aquitania*. What a triumph of enterprise to the Cunard Company and to the naval architect and marine engineer such a vessel represents. I was watching her driving into a north-west gale from the boat deck during the day, a magnificent battle between nature's power and human skill, a sight which arouses one's admiration for the great minds who have raised engineering to so supreme a height and added so greatly to the advancement of civilization.

> 'What does this wilderness of sea portray ?
> A mighty struggle, constant day by day,
> 'Twixt human skill and nature's changing mood.
> The ceaseless roar of North wind's subtle blow,
> The varying power of waves that ever flow.
> Such is man's battle 'gainst this angry flood.'

Mechanical Engineering.

It is difficult to regard mechanical engineering literally as a separate branch of engineering, for although numerically, I suppose, the mechanical engineers exceed the numbers of any other branch, nearly all their duties are associated with other types of engineering.

In connexion with civil engineering all the plant occupied in harbour, dock and railway construction is in the hands of the mechanical engineer. Also in transport and marine engineering the mechanical engineer is largely engaged in the engine building of both locomotives and marine engines and other types of auxiliary machinery for these purposes.

In electrical engineering, although this branch no doubt includes engineers without mechanical training, I would venture to say that the engineer is in an infinitely stronger position if he has received some training first as a mechanical engineer and specialised in electrical engineering afterwards.

A further important branch of the mechanical engineer's work is represented by the maintenance of machinery in the large steel works throughout the country and in the mills and factories of all descriptions. The directors of these companies are largely dependent on the advice of the engineer-in-charge in giving consideration to developments and the introduction of new types of plant to maintain production on an economic basis.

In mechanical engineering I must include the very important subject of machine-tool construction, a branch of engineering which has made very great strides and introduced many changes of design to meet new requirements in the last thirty years. Mass production on an economical basis in many industries has been the direct result of various tool-makers being able to produce special tools confined to the production of thousands of identical articles of a complicated design. I refer to articles produced at a cost of one-tenth to one-twentieth of what would be possible without machine tools specially designed for the purpose.

The introduction of high-speed tool steel enabling far heavier cuts to be taken both by lathes and planing machines has rendered obsolete a large quantity of machine tools throughout the country, and the introduction of the electric drive has also brought about great changes in the design of machine tools. We hear to-day of some works in other countries without a single machine tool at work of pre-war date, a most desirable state of things, but one which, unhappily, the economic circumstances in this country have rendered impossible up to the present time. In principle we have to admit that with our relatively high wages and general charges on industry, taxation, etc., it is not economical to continue to use machine tools which can be superseded by modern tools doing a greater volume of work in a given time, but many firms throughout the country are only able to act on this principle gradually owing to financial reasons.

We hear very strong rumours of the advent of a new type of tool steel, if it can be called steel at all, which is going to bring about a greater change in output than was represented by the introduction of high-speed steel some years ago. If this becomes an accomplished fact it is good news for the toolmakers throughout the country, although it may not be equally welcomed by the many large firms already equipped at considerable capital charge with reasonably modern tools. With such keen competition, however, and the power of over-production at present existing in the country, no firm can afford to ignore the march of progress and will have to recognise the necessity for introducing machine tools of the most efficient type even at considerable financial sacrifice.

May I make a suggestion to the toolmakers in this country? When we are putting down an important new machine tool I find the makers will give every possible help in meeting our requirements in design and output, but they rarely follow up and ascertain what the real performance of the tool has been. To many of them 'no news is good news.' I think this

is a mistake on their part. How many improvements and modifications, probably saving their clients money, could be made if they would periodically send the designer or chief draughtsman round to the works where these machines are actually at work and ascertain at first hand from the foreman and even the workman what criticisms they have to make, and accept for careful consideration any suggestions that may be put forward based on personal knowledge of the output of the machine.

Mining Engineering.

In dealing with this section I propose to confine myself to coal mining, so as to shorten what I have to say, and also to be able to apply myself more closely to the development of coal mining as affecting civilisation.

Prior to the introduction of modern means of transport and the development of the iron and steel trade, the production of coal in this country, both in the aggregate and per colliery, was very small, and, consequently, the amount of virgin coal face exposed at any one time in a colliery was quite moderate. Therefore, the effusion of gas was not sufficiently large as to introduce a serious danger to men working with naked lights. Ventilation was carried out by means of a furnace in the bottom of the upcast shaft, the draught being sufficient for ventilating the moderate area of the workings. Increased production necessitated the adoption of mechanical means of ventilation and large fans were installed. Science had a large share in making colliery development on a big scale possible by the introduction of the Humphry Davy and other safety lamps. These warned the miners of the presence of gas and consequent danger. The much heavier tonnage produced in a given time necessitated the introduction of large horse-power winding engines, and also of wire ropes which would be sufficiently pliable to pass over the pulleys and headgear, and also be strong enough to carry, not only their own weight which in a shaft of 500 yards is not inconsiderable, but, in addition, a loaded cage involving a weight of thirty tons or more.

A sufficient supply of coal at a moderate price is a matter of interest to every inhabitant and manufacturer in the country, and, therefore, any engineering devices which have been introduced to ensure comfort and safety of the miners and at the same time to give us our coal supply for manufacturing and domestic purposes at a moderate price, are of interest to everyone. Although we unhappily know that colliery explosions occasionally occur with very dire results, and regret the many accidents to miners arising out of falls of roofs, &c., those of us who are conversant with coal mining matters realise how much science and engineering have done to lessen the risk under which the miners work. I believe that the public feel that one of the great risks is in winding the men up and down the shaft each day, and yet the careful supervision of winding arrangements, inspection of ropes, and general regulations for the safety of the men are such that, so I am informed, it is only one man in forty millions who suffers an accident from this portion of the miner's duty.

The introduction of vertical ropes as guides to the cages, instead of wooden or steel guides, affords a safe and smooth running of the cages at sixty miles an hour with no more vibration than we experience in travelling in an express train at the same speed. Underground haulage

has been everywhere adopted, so that the use of men for this arduous work, and, to a great extent, ponies also, has been abandoned. This underground haulage is largely carried out by compressed air engines placed underground, as in many pits it has not been felt safe to introduce electric power for the purpose except in the immediate neighbourhood of the shafts. It is true that the electrical engineer has gone a long way in lessening the liability to sparking, and in enclosing the motors so as further to lessen this risk. We are still left, however, with possible danger caused by the cables along the main roads, which however carefully placed are still liable to be damaged by unexpected falls of roof, thereby introducing a potential danger which is difficult to eliminate. At the coal face the engineer up to the present has not been able to do much to lessen the hard manual labour of the working miner, but in thin seams, say up to three feet thick, where manual work on a solid face would be almost impossible, coal-cutting machinery (in which a well-known firm in this city has successfully specialised) has been introduced, thereby lessening enormously the manual work of the miner. I venture the opinion that the introduction of machinery for this purpose has not yet reached its limit.

I regret that more members of the public do not take the opportunity of going underground and seeing the men at work at the coal face. On my various visits I always receive a warm welcome from them, and it is a real education to see what the engineer has done, and under what conditions the men work in producing an article on which we so much depend for the comfort of our daily life.

Electrical Engineering.

This branch of engineering covers a very wide range of subjects and affects our social life almost more intimately than any other type of engineering, except perhaps the supply of good water and efficient drainage installations. It is impossible for me to attempt to cover the whole range of subjects embraced in electrical engineering. Telegraphy, telephony, wireless, electric lighting, electric heating, electric driving, and electric power in their various ranges all enter into and affect the comfort of our domestic life. In considering this branch of engineering as a whole I find it very difficult fairly to divide the credit for its development between the pure scientist and the electrical engineer. The researches and experiments in the early part of last century on the part of Wheatstone, Faraday, and Lord Kelvin, and later, coming to our own time, of Sir Oliver Lodge, Senator Marconi, and other eminent scientists, have undoubtedly prepared the road to the later applications of electricity for domestic and engineering purposes, and no electrical engineer to-day can possibly efficiently carry out his duties without a greater knowledge of pure science than may be regarded as essential in other branches of engineering. It is interesting at this meeting in Glasgow to recall that it was at the British Association meeting in this city in 1876 that Graham Bell, in conjunction with Lord Kelvin, brought to the Association's notice the telephone, and, further, the fact that at the Plymouth meeting of this Association in 1877 I shared with many eminent members of the British Association the interesting privilege of telephoning from the saloon to the bridge on the excursion steamer, with Prof. Graham Bell on board, going to and from the Eddy-

stone Lighthouse. I allude to this fact because in those days it was regarded as a wonderful scientific invention which fascinated the most eminent scientific men. Yet to-day we take it all for granted, and hardly realise the comfort and convenience that the introduction of the telephone has brought into our lives.

I admit that the introduction of wireless telephony and telegraphy has amazed the world to a greater extent than that of the telephone, and it is certainly more within the capacity of the pure scientist than of the engineer to explain the scientific problems involved. I am not going to state whether the introduction of wireless broadcasting into our homes is an amenity or not, *chacun son goût*, but when we turn to the application of wireless telegraphy we accept without hesitation the benefits it has brought into the world. It is impossible to say what number of lives have already been saved by boats in distress having been able to secure help from other vessels by means of wireless communication.

The development of electricity as a mechanical driving power was very slow up to a certain date. For instance, I went by electric train from Berlin to Charlottenburg in the spring of 1882. The running of the railway appeared to be quite satisfactory, and yet it was at least ten, and I think fifteen, years before any real development took place in the way of electric railways or trams, the difficulty, I believe, being in producing satisfactory dynamos on an economic basis. The first electric railways in this country, so far as I know, were the Liverpool Overhead Railway in February 1893 and the Liverpool to Southport Railway in April 1904. The practicability of electric driving on main lines is still a matter under discussion. The only country which has wholeheartedly adopted this system is Switzerland, a country which has undoubtedly been influenced by the uncertainty of obtaining a uniform supply of coal at reasonable prices, coupled with the fact of an efficient and ample supply of water power for their generating stations. The Barberine reservoir, which has now been completed, and the large reservoir at the Grimsel Hospice now under construction, are fine examples of civil engineering work carried out for the purpose of developing electric current for the Swiss railways.

In this country considerable developments are taking place on the various main lines, but engineers are at present concentrating on the use of electric driving mainly for suburban traffic, and not at present on main line long-distance expresses. It is probable that the great extension of high-power installations throughout the country contemplated by the electricity commissioners will render possible a more extensive use of electric trains on our main lines.

The application of electricity for driving purposes in the various large works in this country made very rapid strides as soon as electrical machinery for the purpose was available. I remember showing to a former president of this Association, Sir William White, the first set of Belliss and Morcom engines we had installed in a works in the Midlands, the various machines in these works at that time being driven by steam engines in different shops and line shafting. Sir William said to me then, ' Do you realise that within ten years every machine in these works will be electrically driven ? "
I think few engineers realised at that time that electric driving would replace so rapidly the existing methods. Apart from the economy

represented by its introduction the change enabled the management to register the amount of power used by each type of machine under varying loads of service, a circumstance which was impossible with belt-driven machines, when the power varied according to the tightness and width of the belt. The greater efficiency, however, is really represented by the fact that in a large works electricity can be produced in bulk at a central power station at a low rate of cost, and the loss in distributing to the various departments through high-tension cables and transformers to lower voltage in the different sections of the works is insignificant compared with the saving represented by a consumption of coal and a cost of maintenance far below what is possible with direct steam driving. Electricity has in some measure been introduced into mining engineering, as I have mentioned in the mining section, electric winding engines have been adopted with satisfactory results, but as the fuel supply for steam raising at the various collieries, especially where coke ovens are installed, is much less costly for providing power than in a works without such auxiliary facilities, the economy in the use of electric winding versus steam is naturally not so great.

The public, I think, fails to realise that electric lighting for domestic purposes, if charged at a reasonable rate, does not represent any real charge on the household. It is so clean in its application that, in my opinion, the necessity for cleaning and decorating which is avoided in many cases represents a greater saving than the amount paid for electric light. In addition we have the great advantage that it does not burn oxygen, and therefore we have more healthy conditions in our rooms compared with any other method of lighting. I feel sure that those who have introduced electricity into their houses for the purpose of cooking and hot water supply will never go back to the old system of kitchen fire for this purpose, owing to the former's efficiency and cleanliness in application. It appears to me that all that is wanted for a much larger use of electricity domestically is a reduced charge by the various supplying companies and corporations, at least to the level which exists in many of our cities already. It is hoped that the work of the electrical commissioners in installing bigger units of power throughout the country may bring down the cost so as to place electricity within the reach of every householder.

Since I roughed out this address it has been my privilege to make a journey across America from New York to the Pacific Coast, and return through the Rocky Mountains and Canada, and throughout my journey I could not help realising how large a share engineering in its broadest sense has taken in developing these wide regions. First comes the railway as a through communication between east and west for 3,000 miles. Gradually settlers come and farming and lumber work commences, their progress only being possible with the aid of railway transport. Gradually small towns spring up requiring the assistance of engineers for water and drainage. In the torrid provinces of New Mexico and Arizona the water question is a very serious one, and large irrigation schemes will have to be introduced. At Grand Canyon, for instance, the water for household and farm use is brought nearly 200 miles by train in large special wagons. Then mineral wealth is discovered, and the mining engineer appears and

requires his varied plant to be brought by railway from the manufacturing centres. In the mountainous parts of the country large hydro-electric plants are being developed, thus calling on the electrical engineer for his services, and I might quote many other illustrations of a similar nature.

Yes, ladies and gentlemen, those of us who are spending our lives in engineering work may justly be proud of the large share the members of our profession are taking in promoting and advancing the civilization of the world, and thereby bringing happiness and prosperity to many thousands of our fellow-countrymen.

I realise that within the limits of this address I have only been able to touch to a very limited extent on the association of the different branches of engineering as affecting our civilization. I hope, however, I have said enough to interest my audience in a side of engineering that is not often brought out, and that those of us who are actively engaged in engineering may earn the respect and confidence of our fellow-citizens.

THE ARCHÆOLOGY OF SCOTLAND.

ADDRESS BY

SIR GEORGE MACDONALD, K.C.B., F.B.A.,

PRESIDENT OF THE SECTION.

When I was invited to preside over the deliberations of an important section of the British Association, I felt that a great distinction had been conferred on me. In the interval my appreciation of the honour has not become less high, but my sense of the responsibilities it brings has deepened very considerably. It is no light task for an amateur like myself to endeavour to fill a place that has been occupied by a long line of men eminent in one department or another of the particular branch of science with which we are concerned here. Above all, I fear that, in the scanty leisure which my daily work allows me, it has been hard—perhaps I should frankly say impossible—to find time to concentrate my thoughts on the preparation of an address that should be worthy of the tradition established by my predecessors in the chair. If that does not excuse the discursiveness into which I have been betrayed, it will at least serve to explain it.

Nor is my plea of extenuating circumstances yet exhausted. When I promised to speak to you on 'The Archæology of Scotland,' I contemplated giving you some account of the more recent advances that have been made by workers north of the Border. Since I chose my subject I have been forestalled by the publication of Mr. Graham Callander's paper in the last issue of *Archæologia*. It would be idle for me to try to add anything to that admirably comprehensive and lucid summary, and I can do no more than commend it to your careful attention. The obvious line of approach being thus barred, I have had to cast about for a suitable alternative. In the end one after another of the various possibilities that presented themselves has been set aside in favour of something in the nature of a very general review. To those who are unfamiliar with our problems in Scotland it may be of interest to learn a little of their extent and character and of how they came to assume their present form, while to those upon whom the duty of solving them rests, a backward glance at the progress already achieved may perhaps bring a measure of encouragement and stimulus.

The first movement towards an organised study of Scottish antiquities dates from the last quarter of the eighteenth century. The Society of Antiquaries of Scotland was founded in 1780, and with it there came into existence what is now the National Museum. The leading spirit in the enterprise was David Erskine, eleventh Earl of Buchan. If we may trust Sir Walter Scott, who characterised him as 'a person whose immense vanity, bordering on insanity, obscured, or rather eclipsed, very considerable talents,' Lord Buchan was not altogether a promising sponsor

for the infant science. But at this distance of time we may forgive his eccentricities and honour his memory for the substantial service which he rendered to our common cause. In point of fact, it was probably the first president's very vanity, so severely stigmatised by Scott, that inspired William Smellie to produce his full contemporary 'Account' of the origin of the Society and its Museum with a list, or rather lists, of acquisitions. Lord Buchan's speeches and letters, which are there to be found verbatim, show plainly how limited was the archæological horizon of the age of Jonathan Oldbuck.

Thus in his inaugural address, which maps out the field of the new Society's activities, he states explicitly that the starting-point must be 'the period of the Roman attempts to subjugate the northern parts of Britain.' The monuments which we call prehistoric but which in those days were called Druidical, 'the Cairn, the Mount of Earth, Four Grey Stones covered with Moss'—I am quoting his own words—he attributes to the time of Ossian, and Ossian and his heroes he supposes to have lived in the reign of Caracalla. It is quite consistent with such a perspective that, after a gift of twenty pounds in cash, the first recorded donation to the Museum should have been 'a quantity of Roman arms, consisting of twenty-three pieces of the heads of hasta and jaculum, twenty pieces of the blades, and nine of the handles of the gladius and pugio; a ring, three inches in diameter, fastened to the end of a staple; and a mass of different pieces of these arms, run together by fire, all of brass.' It is not easy to realise that the objects masquerading in this classical garb are the contents of the well-known Bronze Age hoard which was dredged from the marl at the bottom of Duddingston Loch.

Bronze Age weapons, indeed, are systematically labelled 'Roman' in the official record. Nor was it only to weapons that the epithet was applied. The relics of a Bronze Age interment figure as 'an antient sacrificing ax of Roman brass . . . antient Roman cinereal urns . . . and pieces of burnt Roman bones.' That is typical. The men of the Stone Age fare even worse. Their bones are not, it is true, subjected to the indignity of being dubbed 'Roman.' But their relics are sadly to seek among the

'fouth o' auld nick-nackets:
Rusty airn caps, and jinglin jackets
Wad haud the Lothians three in tackets
A towmont gude;
And parritch-pats and auld saut-backets
Before the Flood.'

One or two perforated axe-heads of stone do appear in the catalogue, but they stand cheek by jowl with *lusus naturæ* like 'a chicken, preserved in spirits, having two heads conjoined laterally at the back of the skull.' They are entered, too, under the old-fashioned name of 'purgatory hammer,' an echo of the popular belief that the purpose of placing such objects in graves was to equip the spirit of the dead with an instrument which should be sufficiently heavy to ensure a prompt response to his knocking at the gate of the after-world. Yet, despite the quaintness of these first beginnings, the institution thus cradled has developed, within

a century and a half, into one of the finest archæological collections in Europe. The Earl of Buchan and his friends had builded better than they knew.

The story of our National Museum of Antiquities is a parable. It reflects the process by which, in every European country, the dilettante was transformed into the scholar, the antiquary into the archæologist. There are no general features which can be said to be peculiar to Scotland. *Honoris et pietatis causa*, however, mention must be made of one conspicuous figure. In retrospect Dr. Joseph Anderson towers head and shoulders above the whole of his contemporaries. Emphatically a strong man, alike in intellect and in character, he was endowed with a rare power of accurate observation, a keen sense of the value of evidence, a disciplined imagination, and a singular gift of lucid exposition. It is a fortunate thing for Scottish archæology that its early footsteps should have been directed by so competent a guide. He was in charge of the National Museum for the long period of forty-three years, and the collections as you may see them to-day are, in large measure, the fruit of his energy and discriminating zeal. But he did much more than merely stimulate their growth. He used them as material for that invaluable compendium of Scottish archæology which he embodied in his successive series of Rhind Lectures. The first of these was delivered as long ago as 1879. The intervening period has added much to our knowledge, so that, in the light of the fresh information now available, the details require to be corrected here and there. More frequently they require to be supplemented. Anderson lived to see the emergence of Azilian man at Oban and on Oronsay, as well as the first discovery of Tardenoisian flints on this side of the Tweed. He died before we had any hint that human beings might have tenanted the caves of Sutherland in palæolithic times. But none of these new factors affect in the slightest degree the principles which he enunciated so cogently. The lines which he originally laid down have had to be produced backwards. Otherwise they remain unchanged. Their permanence is due to the method of treatment he adopted. To him archæology was an inductive science in the strictest sense of the term. If its potentialities were to be fully realised, it must cut itself ruthlessly adrift from history. Here is one of his characteristic utterances: 'Archæology has no dates of its own—gives no periods that can be expressed in chronological terms. These belong exclusively to history; and, in point of fact, it is impossible to obtain such dates or periods except from record.'

There are modern writers to whom that may seem a hard saying. Yet, on Anderson's view of what archæology meant, it is fundamentally and incontestably true. Listen to his summary of how the materials of his science ought to be dealt with: '(1) By arranging them in groups possessing certain characteristics in common; (2) By determining the special types of which these groups are composed; (3) By determining the geographical range of each special group; (4) By determining its relations to other types within or beyond its own special area; and (5) By determining the sequence of the types within the geographical area which is the field of study. The general outcome of the whole dealing of the archæologist with his materials is thus the contruction of a logical history of the human occupation of the area which he subjects to investigation—that is, a history which is not

chronological, and can never become so, unless where it touches the domain of record, and by this contact acquires an accidental feature which is foreign to its character.' Applying this method rigidly, not merely to the prehistoric objects in the National Museum and elsewhere, but also to the widely scattered structural remains, with many of which he was personally acquainted and some of which he had himself excavated, he built up, without extraneous aid of any kind, a framework into which he was able to fit the whole of his materials in such a way that each appeared in its proper sequence and carried its proper significance.

As might have been expected, it turned out that the pre-history of Scotland has much, very much, in common with the pre-history of other areas. But it also turned out that the country contains groups of monuments and classes of archæological objects, to which no parallel can be adduced from any other part of the world. Scotland, in a word, has an archæology of its own. The Scottish brochs, for instance—those strange towers of dry-built stone with chambers in the thickness of the wall and no opening towards the outside save a very narrow doorway—are peculiar to the area. Hardly less characteristic is one of the principal varieties of Scottish earth-house. Similarly the so-called ' Pictish ' symbols on the sculptured stones stand quite alone, as do the heavy silver chains on which they occasionally appear, and the massive bronze armlets and carved stone balls of a somewhat earlier age. Finally, as regards the archæological material generally, Scotland enjoys in one important respect a distinct advantage over her southern neighbour. Her mediæval monuments may always have been relatively few and inconspicuous. Certainly her castles and her abbeys and her cathedrals have too often suffered grievously from hands that were bent on malicious and wilful destruction. But her prehistoric remains are extraordinarily numerous and, ruinous as the condition of many of them is, they are not seldom sufficiently well preserved to offer a rich field for scientific investigation.

The first thing needful is a proper survey of the ground. That is being carefully, if slowly, carried out by the Ancient Monuments Commission, who have already dealt with several of the districts that are of most interest to the student from the prehistoric point of view. The reports on Sutherland, Caithness, Galloway, Skye and the Outer Isles have all been published. Orkney and Shetland are under examination now. Argyll and Bute, Aberdeen and Kincardine, Peebles and Roxburgh will follow in due course. When these have been completed a long step forward will have been taken. But something more than a proper survey is required. It should be accompanied by systematic and well-directed excavation. How much we might expect to learn in this way you may gather from Mr. Callander's account of the harvest that has been reaped by isolated individual effort. Only in one sector has there as yet been any approach to an organised attack, but the results obtained there are surely of good omen. Within the last thirty or forty years, thanks to the enterprises carried out by the Society of Antiquaries and the Glasgow Archæological Society, the story of the Roman occupation of Scotland has been largely rewritten. Much remains to be done. But to those of us who can recall the days before 1890, the transformation that has been wrought is remarkable.

No doubt the conditions in this particular sector were specially favourable. The Romans are always popular, and it has never been difficult to stir up a lively interest in the search for any traces they may have left behind them. Again, it has been of immense service to have available for comparison and guidance the fruits of the labours of those who were simultaneously working on analogous problems in England and on the Continent. Finally, progress invariably tends to be more rapid when there are visible landmarks by which the rate of advance can be reckoned, and the Roman period is a period in which archæology is continually making contact with history—in which, indeed, the ultimate test of success is the extent to which the two can be blended into one. In the nature of things it is impossible that the last of these three advantages should ever be enjoyed by students of epochs which cannot by any stretch of imagination be brought into connexion with written record. With the remaining two it is otherwise. In the first place I believe that public interest would respond readily to stimulation—and the case of Traprain Law shows that in such matters nothing succeeds like success. In the second, the opportunities for comparative study are already considerable, and are multiplying under our very eyes. Only the other day we had the pleasure of welcoming to Scotland as our pioneer professor of Prehistoric Archæology a scholar who has won his spurs in the Central European field. Now that he has made his home in our midst we may fairly venture to ask him: 'Are not Forth and Tweed, rivers of Scotland, better than all the waters of the Danube?' If he can be persuaded to adopt this point of view, I am confident that the happiest results may be anticipated when he has had time to organise research and to train the researchers.

Professor Childe, I understand, has already been exploring Caithness and the Orkneys. I am sure that, as he extends the range of his voyages of discovery, he will be more and more deeply impressed with what I singled out as one of the distinctive features of Scottish archæology—the richness of the prehistoric material that is still available for study. It may be worth while glancing at the reasons for this wealth. In all ages the distribution of population in a country is determined by economic considerations. It is obvious that men will elect to dwell in the regions where they can most readily obtain the means of subsistence, and it is equally obvious that in every country these regions will vary periodically according to the stage of civilisation that has been reached. To-day, for instance, the English Midlands are blackened by the smoke of innumerable chimneys, whereas in Roman times their damp and chilly soil was virtually untenanted. Our prehistoric forefathers found much of Scotland thickly wooded. The forests and the dense undergrowth must indeed have rendered it altogether unfit for occupation. Until the use of metal, and particularly of iron, had been adequately developed, systematic clearing would be impossible. Consequently, as the survey of the Royal Commission proceeds, it becomes increasingly plain that the prehistoric settlers tended to congregate in the areas which, for climatic or geographical reasons, were treeless in prehistoric times. But these are precisely the areas in which, under modern conditions and judged by modern standards, the land is least productive. As more fertile districts were opened up by the felling of trees and the draining of marshes, they became less and less

worth the trouble of cultivation. Time has, therefore, dealt more tenderly with the monuments than would have been the case had they been exposed to constant danger from the plough and the pickaxe. Often the only damage they have suffered has been through natural decay.

Thus much for their state of preservation. What about their number? To the uninitiated this must always seem surprising. It has been calculated that in Aberdeen and Kincardine alone there are some 200 stone circles. These, of course, are of the Bronze Age. Equally worthy of note is the abundance of remains belonging to the Early Iron Age. Thus the Inventories of the Royal Commission actually register as many as 67 brochs in Sutherland and no fewer than 145 in Caithness. If the pottery and chambered cairns of the Neolithic Period are less spectacular, they are hardly less remarkable. In a word, it is not open to doubt that, in the days before history began, the North of Scotland and the Western and Northern Islands carried a population that was relatively very numerous. The contrast with the scene of desolation which they now present is often very striking. The stone circle of Callanish in Lewis, for instance—in itself almost as impressive as Stonehenge—is situated in a veritable valley of vision. There are seven such circles within four miles of Callanish. As the eye turns from these gaunt monuments, rising here and there from the silence of the heather-clad hills, and rests for a moment on the straggling hamlet by the shore, the words of Isaiah spring to the lips: 'Behold, the Lord maketh the earth empty, and maketh it waste, and turneth it upside down, and scattereth abroad the inhabitants thereof.'

How can we account for the change? The solitude of to-day is easy enough to understand. It is the density of population in prehistoric times that calls for explanation. Various theories have been put forward. Only the other day, for example, I saw it seriously suggested that metal may have been the lure which attracted prehistoric peoples to the Western Isles. The theory has the glamour of romance, but I am afraid that it will not do. The Western Isles are not metalliferous and, in any event, we have got to reckon with a Neolithic population, who would certainly not go in search of something of whose very existence they were unaware. I am disposed to believe that the true solution of the problem is much simpler and that, as usual in such matters, the key will be provided by geography. That means distribution maps. As yet our supply of these is far from adequate. Imperfect as it is, however, it may prove sufficient for our present purpose, more especially as we can fortify ourselves by an appeal to the sister-science of history.

Nowadays the vast majority of those who invade the Highlands and Islands approach them by way of Southern and Central Scotland. I have already indicated that in prehistoric times that avenue was barred. The Caledonian Forest, which spread far southwards into what we regard as the Lowlands, must have been an impenetrable obstacle. The early immigrants arrived by sea and reached the mainland *via* the Western Islands. This implies that they came from Ireland, and that it is in Ireland that the roots of Scottish prehistoric civilisation must be studied. At the moment, however, we are concerned, not with studying the roots, but merely with establishing a connexion between them and the full-grown plant. In other words, all that is necessary is to satisfy ourselves

as to the set of the current of migration. It is significant that as late as the dawn of the historic period it was flowing strongly towards the north and east. The Scots themselves were, of course, incomers from Ireland and, if we can trust Continental analogies regarding the movement of peoples, we may assume that the foundation of the kingdom of Dalriada was preceded by a prolonged process of gradual infiltration. I have more than a suspicion that the troubles which the Romans experienced, and in particular the restlessness which compelled them to abandon the Forth and Clyde wall, were in no small measure due to the encouragement which the turbulent natives received from the passage of a steady stream of reinforcements across the narrows of Stranraer.

But the case for migration from Ireland in prehistoric times rests upon a basis more stable than analogy. Further excavation and an ampler supply of distribution-maps are needed to make it complete, particularly for the Neolithic Period. The evidence, however, is already considerable enough to furnish what may perhaps be accepted as convincing proof. Some years ago Mr. A. O. Curle, in his Rhind Lectures, drew attention to the testimony supplied by cup-and-ring markings. Such markings, he pointed out, are recorded as occurring in twenty counties—Wigtown, Kirkcudbright, Roxburgh, Berwick, Ayr, Bute, Argyll, Dumbarton, Lanark, Mid and West Lothian, Peebles, Fife, Clackmannan, Perth, Forfar, Ross, Aberdeen, Sutherland and Caithness. The Royal Commission's survey of North Uist and Benbecula enables us to add Inverness to the list. But, for the proper interpretation of the record, Mr. Curle went on to say, we must have regard to the number of examples that have been noted in each of the various countries. The poverty of the three shires that march with England—Berwick a single example, Roxburgh two, Dumfries none at all—precludes the idea that the folk responsible for these mysterious sculpturings entered Scotland by crossing the Border. On the other hand, the area in which the markings are found in greatest number and with the greatest variation of device and complexity of design is exactly the region that lies over against Ireland—the coastal districts of West and South-West Scotland. They abound in Wigtown and Kirkcudbright, and are still more common in Argyll. As they are also frequent in Ireland, the inference seems plain.

Cup-and-ring markings, in Scotland at least, must be associated with the phase of culture that was distinguished by the use of bronze. To discover what happened during the phase that succeeded it we may turn to the brochs. At the outset it has to be admitted that the broch was not imported from Ireland. There are no brochs in Ireland. The broch is a purely Scottish creation, evolved on Scottish soil. Nevertheless it is hardly possible to doubt that it was from the shores of Ireland that the ancestors of the broch-builders originally came. They certainly did not make their way into Scotland across the Border, any more than did the men who carved upon the rocks those mysterious cups and rings. There are no brochs at all in Dumfries or in Roxburgh. It is true that Berwick, Selkirk and Midlothian can boast of one apiece. But that is a paltry display compared with Orkney's 70 and Shetland's 75. Nor is it only their rarity in the south that is significant. The three sporadic examples I have named seem to show the characteristic features of this type of

structure already fully developed. And the broch did not spring full-grown from the brain of some architectural genius of the prehistoric period: it was the outcome of a slow process of evolution. The southern brochs can only have been built by intruders from the north.

We may go further. Seventeen or eighteen years ago, in surveying Sutherland and Caithness for the Royal Commission, Mr. Curle noted certain points which seemed to him to indicate a gradual improvement in the type as one moved inland from the western coast, and he saw in this—rightly, as I think—a clue to the drift of the population. His deduction has received remarkable confirmation from the Commission's recently published survey of Skye and the Outer Isles, as well as from the late Dr. Erskine Beveridge's investigations in Tiree. In the insular region we find brochs in reasonable abundance—44 are recorded there by the Royal Commission—but we also find numerous specimens of what can best be described as the broch in the making. The so-called 'semi-brochs' of Tiree, the 'galleried duns' of the Hebrides and Skye, all alike appear to represent experiments in the architectural form which was destined to have its fullest expression on the mainland. As the broch-builders moved farther north and then farther east, they carried with them the fruits of their ripening experience.

The facts of early Scottish history and the inferences as to the Bronze Age and the Early Iron Age are thus in complete accord. They bear out the view—in itself *a priori* probable—that for uncounted generations the trend of migration was from the direction of Ireland through the islands of the west coast to the north of Scotland. We may reasonably assume that an exhaustive examination of the chambered cairns, in continuance of the work carried out with such marked success by Professor Bryce, would give a similar result for the Neolithic Period. But, once the set of the current has been determined, it is not difficult to understand why regions, where the sheep and the deer now wander at will, should have been thickly populated in prehistoric times. Although the causes that prompted the movements of peoples in those far-off days are obscure, one of the most potent was certainly the demand that would be created for fresh means of subsistence when the mouths to be fed were multiplied. At intervals a surplus of humanity would be spilled from Ireland. In front there stretched but one open road, and that was a *cul de sac*. For, to those who followed this route, Northern Scotland was literally the end of the world. Long afterwards, under the pressure of a similar urge, a similar stream descended from Scandinavia. But the later immigrants came in stout ships, and could at need deflect their course, as they did, to the Faroes, to Iceland, even to Greenland. With the earlier wanderers it was different. When they had reached Unst, they would scan the horizon in vain for any sign of land to tempt their frail craft further. The ocean was an insurmountable barrier. The flow from the south would be brought to a standstill on its shore, and the more nearly that limit was approached the greater would the congestion of population tend to become. This, I think, is the real secret of the abundance of Scotland's prehistoric remains.

SECTION I.—PHYSIOLOGY.

THE RELATION OF PHYSIOLOGY TO OTHER SCIENCES.

ADDRESS BY

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PRESIDENT OF THE SECTION.

Our subject of physiology has developed so rapidly during the last few decades, has taken so definite a place among the sciences, and has such intimate relations with other subjects, that its position as a branch of natural knowledge is one of some general interest.

Physiology has a threefold appeal—as the master-key of medicine its practical value is self-evident, as a science it has now a distinctive position, while its relations to philosophy command the attention of all thoughtful men. We will consider it, for convenience sake, from these three standpoints.

From the earliest times, physiological knowledge, whether known by that name or not, has had the closest association with medicine. It would indeed be difficult to imagine any great advance in the one that was not immediately reflected in the other. Their methods, though necessarily different, are convergent, their meeting-point being the disclosure of normal functions. It is the business of the physician to attend to the urgent call of pain and disease, and to use for their relief such information as he has at his disposal. As he does so he observes, compares, and draws conclusions on the basis of which a theory of the causation of the disorder may be built. The clinical observations and deductions drawn from them give a basis of rational physiological theory from which we have learnt that a state of disease is never a thing in itself, but is always a result of a quantitative change in some physiological process, an increase or diminution of something that was there to begin with. Reflection upon the observed bodily states in, say, a fever, jaundice, diabetes, nephritis, or even mental disorders, reveals only overaction or underaction of some physiological function as the feature which distinguishes the affected from the normal individual. It is perhaps easier to speak of the normal than to define it. In the long run, the normal is the description given by a majority of individuals of their own build or behaviour. It is abnormal to have unequal legs, to be eight feet high, or to believe the earth is flat; but as no two individuals are exactly alike the definition of normality is more a matter of a statistical average than of precise definition.

Disease is a departure from the normal which threatens life or which in some way reduces its value. The physician's duty with regard to it is a threefold one; he must diagnose, prognose and treat. In diagnosis and

prognosis he relies chiefly on past experience, and must also bring great skill and judgment to bear on each particular case. The symptoms of disease which enable him to make a diagnosis are very often of an adaptative or compensatory nature, and the application of physiology to the problems of medicine is often of considerable value from this point of view, since it teaches that the mere alleviation of symptoms may be quite the wrong way to attack the problem. In cardiac or renal dyspnœa, for example, the exaggerated breathing is of an adaptative nature—the patient is not ill because of the overbreathing but overbreathes in consequence of the disease and would possibly succumb if he did not. More usually the meaning of symptoms is less clear, and it is the difficulty in recognising the underlying causes of disease which makes the practice of medicine at once so exquisitely difficult and so fascinating.

In treatment, too, two important principles arising from actual observation receive support from physiological knowledge. One is that the consequential alterations which take place in the course of the disease are of the nature of adaptations which tend to restore the function to normal; these adaptations take the form of increase or diminution of some particular factor, of hypertrophy or atrophy often of some definite organ, always of some function—it is, in fact, the *Vis medicatrix* of the older physicians, the underlying principle of expectant treatment. The other principle is that nearly all positive measures of treatment, including drugs, produce their effects by augmenting or restricting some function or other.

The applied aspects of physiological knowledge concern the related subjects of hygiene and preventive medicine, medicine, surgery, and veterinary and agricultural sciences in their widest senses.

Investigations on diet, ventilation, industrial fatigue, and on the contraction of and resistance to infections, soundly based on the fundamental principles of physiology, have done much to make conditions of life more tolerable for the present generations than for their predecessors. Few medical students at the present time become acquainted with those severe or fatal cases of rickets, scurvy, diabetes or pernicious anæmia which we all knew could be seen in the wards of any large hospital twenty years ago, and this gift of life and health to the afflicted is the grateful offering of physiological research to its respected parent, medicine.

No aspect of scientific activity is so generally misunderstood as that which concerns the making of discoveries, and in matters of medical research ignorance is particularly widespread.

The popular idea seems to be that an investigator sets out with the intention of making a particular discovery, such as a new element, or a cure for a certain disease, but every scientific worker knows that real discovery, as distinct from invention, is never achieved in this way. A discovery is the process by which an idea of new relationships is revealed, and involves two factors, observation and reflection. The origin may be a chance observation which suggests a hitherto unappreciated relation, and leads to the formulation of an hypothesis which, if possible, is then deliberately tested by experiment. The history of the discovery of insulin may be given as an illustration. The fundamental discovery here was made by a chance observation that removal of the pancreas produced

diabetes; from that time onwards it was evident that if the missing pancreatic function could be replaced a cure would be possible, and it was justifiable deliberately to search for some means of doing this. But the search was in vain until another new idea came into physiology by reason of the discovery of the existence of autacoids. From this point on all was clear in theory, and it is no detraction from the merit of subsequent work to say that the final happy result depended principally upon inventive technique and manipulative skill, and only in a lesser degree upon discovery.

Discoveries are infrequent, in a sense fortuitous, and often dependent on rare qualities of intellect as well as on accurate observations, and they mostly come out of the fullness of time.

We all feel great pride in recalling that one of the greatest of all discoveries, which has recently been celebrated at the tercentenary of the publication of William Harvey's famous book "*de motu cordis*," was made in our own country. Here was a genuine revelation that put old facts in a new light. It is of interest to reflect that the hospital at which Harvey was a physician had been carrying on its work as such for over 500 years at the time his discovery was made. What fundamental changes in the outlook of the physician and surgeon has that hospital seen during the ensuing 300 years in consequence of his revelation! And what further mutations in thought and practice will it have witnessed when Harvey stands as a beacon half-way in its eventful history? For we are privileged to live in times pregnant with opportunity for the science of medicine.

Incidentally it has been claimed, with more audacity than insight, that experiments upon living animals serve no useful purpose, and it has even been pretended that Harvey had no need for such experiments in the classical researches which formed the foundations of physiology and gave reason to physic. Yet we have Harvey's own words. . . . 'At length, and by using greater and daily diligence, having frequent recourse to vivisections, employing a variety of animals for the purpose, and collating numerous observations, I thought that I had attained to the truth, that I should extricate myself and escape from this labyrinth, and that I had discovered what I so much desired, both the motion and the use of the heart and arteries.'

The experimental method, which was revived by Harvey, now forms the permanent basis of physiological as of medical knowledge, and in spite of all criticisms must obviously remain so. Riolan, in advancing against Harvey the criticism that 'it is a mockery to attempt to show the circulation in man by the study of brutes,' was, as Gley has recently remarked, 'already employing the argument, if it can be called one, which is encountered under the pen of the antivivisectionists of all times, and which illustrates the diuturnity of ignorance and folly.'

Let anyone with sufficient acquaintance with physiology try to write an account of such of the main facts concerning the functions of the heart and of the circulation as are most valuable in medicine, without reference to any fact obtained directly or indirectly by animal experimentation, and he will find his essay a very sorry one indeed: for no doctor can use a stethoscope, feel a pulse, take a blood-pressure, administer a hypodermic, give an anæsthetic or a transfusion, perform any modern

operations, or indeed take any steps in diagnosis, prognosis or treatment, without utilising at every turn knowledge derived from the results of animal experimentation and obtainable in no other way. And every medical man, even those few who for various reasons prefer the publicity of an antivivisection platform to the obscurity to which they are properly entitled, knows these things perfectly well, and if he practises, acts upon them every day of his life.

Another useful application of physiological knowledge is that of the science of ventilation, including the use of mine rescue apparatus, which began to take shape during the eighteenth century in the hands of Stephen Hales, while a little later Joseph Black, a professor, be it noted, of medicine and chemistry in this ancient University of Glasgow, discovered carbon dioxide, and Priestley oxygen. The use of submarines, of oxygen sets for aviators and mountaineers, of gas respirators and caissons, and the means for the scientific study of industrial fatigue and of athletic performances, have all descended as practical outcomes of this respiratory physiology.

To take another example in more recent times one may mention Joseph Lister, a cherished link between University College, London, and the University of Glasgow, that indefatigable experimenter who made as valuable contributions to physiological knowledge as to surgery. The revolution in surgical technique which we owe to his largely physiological investigations is as striking as the changes in the outlook of medicine introduced by Harvey. Erichsen, a teacher of Lister, had said not long before that operative surgery had reached the limit of its perfection and that the surgeon's knife would never safely penetrate such parts as the brain, chest or abdomen.

The subject of pharmacology is very closely connected with physiology on the one hand and therapeutics on the other. As a branch of physiological work it has the highest scientific as well as practical importance; for the study of the mode of action of drugs by providing a means of studying the effect of definite chemical alterations in the environment on the reactions of the living cells cannot fail to serve as a powerful instrument of physiological research. Rational therapeutics, based on the results of pharmacological study, also will carry into the wards the spirit of true scientific investigation, and the provision of beds in some hospitals for the use of the Professor of Therapeutics is an indication that definite progress is being made in this direction. Such an advance has not come before it is needed. If the medical practitioner is to compete successfully with osteopaths, chiropracters and other similar unqualified persons, he is most likely to do so by only prescribing treatment with proper scientific basis. He should be able to form some opinion with regard to the claims of advertisers of remedies who contribute so large a share towards his daily mail deliveries, and many of whom would be unable to exist were it not for the fact that the average doctor is often as easily deceived with their pseudo-scientific puff as any layman.

If physiology may with pride point to the way in which it has contributed to the development of medicine, surgery, hygiene, and veterinary science, it must with gratitude acknowledge that its inspiration has largely come from them too. A clinical friend of mine has written that

'physiology can only come to the aid of medicine with becoming modesty, and without overweening dogmatism. There is no finality about either, but they can co-operate usefully . . .' and I thoroughly agree with him, not only because I recognise, as a physiologist, that my subject has been nourished largely by the problems of the bedside, but also because I think that modesty is the only attitude compatible with the ignorance of all of us when we view the handiwork of nature however revealed.

At this point I would like to digress a little to say a few words about the training of medical students in physiology. This has two objects in view, first to equip these students with a grasp of physiology such as will enable them later on to build a proper rational knowledge of medicine and surgery; second, to encourage them further to advance medical and surgical knowledge, and in special cases physiology itself. With certain reservations, I do not think that these two objects are at all incompatible at the present time.

A hundred years ago the common portal of entry into the medical profession was by a preliminary apprenticeship, begun at the age of about fourteen, to a doctor or apothecary, as often as not in the country. This lasted for five years, after which it was usual for the student to 'walk the hospitals' at some great centre, the chief in London being St. Bartholomew's and Guy's Hospitals. Here he could also attend some lectures on anatomy (including physiology), botany, medicine, surgery and midwifery, and there were also courses of dissections. The requirements of licensing bodies were, however, fragmentary. The College of Physicians had no definite curriculum of professional study before 1845. In Scotland physiology was incorporated, as the 'Institutes of Medicine,' with some teaching of general pathology and elementary clinical medicine.

The medical students of Dickens—for example, Bob Sawyer, who 'eschewed gloves, and looked upon the whole something like a dissipated Robinson Crusoe'—were caricatures of the students of this period.

There were few medical students in England outside London a century ago; Oxford and Cambridge together averaged six medical graduates a year. Edinburgh produced about 100–120. In England it was only the handful of University men who received anything like a preliminary education before entering hospital.

A notable step was taken in London with the foundation of University College, then called the University of London. In his introductory address at the opening of the University in 1827, Sir Charles Bell said: 'With respect to our students, the defects of their mode of education are acknowledged on all hands. They are at once engaged in medical studies without adequate preparation of the mind; that is to say, without having acquired the habit of attention to a course of reasoning; nor are they acquainted with those sciences which are really necessary to prepare for comprehending the elements of their own profession. But in this place this is probably the last time they will be unprepared, for example, for such subjects as we must touch to-day. In future, they will come here to apply the principles they have acquired in other class rooms to a new and more useful science.'

In the first year 165 students entered the new college, and classes were

held in chemistry, zoology, anatomy (and physiology), and on various clinical subjects.

Jumping forward now about forty years to 1867, we find the curriculum has expanded very much. First, there came the influence of Liebig and chemistry, and by about 1850 or 1860 we find chemistry, mostly inorganic, a regular requirement by all licensing bodies. A chemical laboratory was first constructed at St. Bartholomew's for instance in 1866. The University of London now required at a pre-clinical examination a knowledge of chemistry, botany, natural philosophy, anatomy, organic chemistry, physiology and materia medica. A contemporary writer gives an account of the students of this period from which it appears that the medical student has since changed more in appearance than in ways, for he says that the principal aim of some of them was preservation of their glossy hats and exquisite coat-tails, gloves and sticks, while the throwing of paper balls was already an established tradition among them.

Although lectures on physiology are mentioned at this time, there was no separate Chair of Physiology in England until 1874, when Sharpey, who had been Professor of Anatomy and Physiology at University College, was succeeded by Burdon Sanderson as the first Professor of Physiology. The first practical classes in Physiology were held there by a pupil of Sharpey, Michael Foster, and consisted of histology, experimental physiology and rudimentary physiological chemistry. To quote Foster's own words, 'What could be done then was very, very little. I had a very small room. I had a few microscopes. But I began to carry out the instruction in a more systematic manner than had been done before. For instance, I made the men prepare the tissues for themselves. That was a new thing in histology. And I also made them do for themselves simple experiments on muscles and nerves and other tissues in live animals. That, I may say, was the beginning of the teaching of practical physiology in England.'

We realise from these dates that Physiology in Britain had fallen very far behind when compared with the Continent, for Ludwig, in Germany, who obtained a separate Chair of Physiology in 1865, and Claude Bernard in France, had raised the subject to a high level by the time that Physiology in England was being reborn, through the activities of Sharpey and his pupils Foster and Burdon Sanderson.

The teaching of physiology is, very properly, largely influenced by contemporary research work, and the exact matter taught must, therefore, be expected gradually to undergo change as the focus of research interests shifts.

It was only natural that the new English physiology should receive the stamp of the men who recreated it, and that histology through Sharpey, and nerve-muscle physiology through the influence of Burdon Sanderson, should occupy a prominent place. For about thirty years in fact the nerve-muscle physiology threatened to eclipse all other branches of experimental work, and it was this flight into questions which appeared to be chiefly of academic interest which was, I think, largely responsible for the regrettable estrangement between the newly liberated science and its parent subject of medicine which marked that period of its development, and of which traces still linger to this day in some of the more elderly representatives of both subjects. At the present day we must admit that the

knowledge gathered by those of our predecessors who worked at the physiology of muscle and nerve has proved of great value in directing physiological inquiry along scientific lines, from which the science of medicine has profited as much as physiology itself. The interesting revival of the study of the same subjects by more accurate methods within the past few years has further enriched our insight into the fundamental phenomena of life and vindicated the opinions of our predecessors as to the value of such investigations.

The development of physiological chemistry, now often called biochemistry, in this country was largely due to the influence of Prof. W. D. Halliburton, whose ‘Chemical Physiology and Pathology’ was for many years the only comprehensive English textbook on the subject. The growing importance of organic chemistry led to its introduction into the medical curriculum, in connexion with biological chemistry, and in recent years the similar position of physical chemistry has led to its inclusion in some form or other in the curriculum of most medical schools.

Whereas in the sixties the student's chief study was anatomy with some botany and chemistry, there have now grown up as special courses of instruction, each with its professor or other specialised teacher, courses in the preliminary sciences and in anatomy, neurology, histology, embryology, organic chemistry, physical chemistry, physiology, experimental physiology and biochemistry, with pharmacology often thrown in as a makeweight to fill up any spare time the student may have left. Sometimes even special courses of human physiology are added. Here is the great dilemma of the medical curriculum: with all these special departments, each urging that its subject is of prime importance in the course, how can the poor student rightly direct his steps, and be enabled to see the wood for the trees? Yet, so great is the expansion in each of these subjects, that unless some at least of them are dealt with by specialists the student's instruction will unquestionably be obsolete in parts.

The solution to the difficulty lies, in my opinion, in two directions: first in the extensive modification of the present system of examinations, and secondly in the exercise of a sympathetic understanding on the part of specialist teachers of the difficulties of the student and a proper perspective of the relation of his own subject to the requirements of the curriculum as a whole. We have a sacred trust: it is the duty of those of us who are teachers of physiology to hand on to our successors, not the science as we inherited it, but a science which we and our contemporaries have ourselves improved and enriched to the best of our ability.

Out of the multitudinous and tumultuous activities of scientific labour new principles gradually emerge, and the truth appears in a constantly changing garb. As I have said before, research reflects itself in teaching, and it is accordingly necessary that teaching should be reviewed from time to time, that new matter be introduced in so far as it is of general importance, and old matter rejected as soon as its immediate value diminishes. I should very much like, for similar reasons, to see profound alterations in the teaching of chemistry, both inorganic and organic, to medical students.

It is, in my opinion, quite impossible, and perhaps undesirable, at the present time to frame instruction in physiology so as adequately to equip

the ordinary medical student to proceed directly to the prosecution of research in any of its branches; this can only be achieved by a further year or two of study of the subject, such as by a science course for an honours degree. One of the objects of instruction is to enable the latest results of physiological investigation to be utilised in the clinic, and it seems to me that one of the best ways for this to be effected is for some workers specially trained in physiological methods to enter the staff of clinical units where facilities for research work are at hand. The opinion was at one time prevalent among many clinicians that if their problems required the use of methods similar to those of experimental physiology these should be farmed out to a physiologist, and although there are cases where this procedure may be followed with advantage, the rich harvest which has already been reaped by the importation of physiological knowledge and methods into, rather than the export of problems from, the clinic, is adequate justification for the former. It is in any case encouraging to note the present-day decline of the attitude that experimental investigation is work of a lower order, which can be put out like so much washing, for the employment of an inferior caste. We at the present day, however we may be labelled, are not merely willing to admit, but eager to assert, that we cannot recognise fundamentally distinct methods of physiology, of psychology, of medicine, of chemistry, or of physics; we only admit a method of experimental inquiry common to all science and slightly modified to suit particular cases.

The close connexion which is now generally admitted between physiology and medicine was clearly foreseen by Claude Bernard in 1855. Medicine, he said, is a science, and physicians who describe it as an art injure it, because 'they exalt a physician's personality by lowering the importance of science.' 'True experimenting physicians,' he says, 'should be no more perplexed at a patient's bedside than empirical physicians. They will make use of all the therapeutic means advised by empiricism; only, instead of using them according to authority and with a confidence akin to superstition, they will administer them with that philosophic doubt which is appropriate to true experimenters.' And this attitude, I venture to think, is the one which is almost universal to-day.

Scientific Aspects.

Physiology takes its place as a science in proportion as its data are accurate and its principles fall into line with those in the other sciences. My great teacher Starling said that science has only one language, that of quantity, and but one argument, that of experiment. The qualitative observations of one generation tend to become quantitative at a later stage of development of a science, and the degree of development of a science can indeed to some extent be judged by the extent to which it falls into a scheme of the unity of science by giving results which are capable of mathematical treatment and of expression in broad general principles.

I recollect that when I first took up the study of chemistry the acquaintance of most chemists with any of the branches of mathematics was so slight that there was on the market a book on arithmetical chemistry. Shortly after that time the progress of physical chemistry on the Continent

had become so definite that it came to be considered quite a useful thing for a chemist to acquire some knowledge of the higher mathematics, and the appearance in Britain of a textbook of higher mathematics for students of chemistry and physics rendered great service by introducing the kind of mathematics that was likely to be of value in application to these subjects.

What has happened in physics and chemistry may be reasonably expected to happen in biology so soon as it is able by improvement in the accuracy of its methods, and by progress in the formulation of its problems, to employ mathematics with profit in the manipulation of data and in the construction of those generalisations which are landmarks of progress in all the sciences; indeed we are, I think, now witnessing the commencement of such a phase in the development of our own subject. The many facets of physiological inquiry make it incumbent on all of us to possess some knowledge of one or more related subjects, and I know of no more promising collateral subject which a young physiologist could take up at the present time, as an alternative to chemistry or biology, than the study of mathematics. But those who do take it up should do so for the purposes of utilising it in their own experimental work, not merely for the purpose of surveying results obtained by others, and still less in order to 'lend an air of verisimilitude to an otherwise bald and unconvincing narrative.' Mathematics is a most valuable aid to reasoning, and it can be of no real use to physiology except when it leads to clarification of thought both of an author and of his readers. Under any other circumstances its introduction into biological literature is, I think, of extreme danger, because of the superstition, common alike to those who write and those who read, that anything expressed in mathematical form must be accepted as correct without any further question.

Mathematics and mathematical physics have been of considerable use to physiology in increasing the accuracy of its experimental data, and this in two ways. First, by bringing the accurate experimental and intellectual methods of physics to bear on the construction and use of the numerous physical instruments which it employs. It has been said by Prof. A. V. Hill that many of the early investigations on muscle were in reality studies of the properties of levers, and it is certain that similar remarks apply to only too many investigations in which the properties of the apparatus used have not been suitably investigated. As illustrations of the value of mathematical-physical study of apparatus one may mention the classical investigations of Frank on hæmodynamical recording apparatus, the fundamental treatment of string galvanometers and similar instruments by Einthoven, the correction of capillary electrometer records by Keith Lucas, and the vast improvements in galvanometer systems effected by Downing and Hill.

Even when the apparatus at the disposal of the physiologist is unexceptionable, however, it is often the fact that, owing to the nature of the subject, results are not susceptible of repetition with the same ease and certainty as are those of chemical or physical experiments. The variability of the results is due in such cases to what are called accidental circumstances, a term which in reality means circumstances over which we have no control, owing either to our ignorance of their nature, or else to our

inability to alter them. In those cases where further study provides methods of more fully understanding and therefore more adequately controlling these circumstances, valuable results follow almost at once. For instance, certain of the obscure causes of different behaviour under particular conditions are inborn, and can be controlled by the use of inbred strains of animals such as those of the standard inbred white rats; or again, one may mention the far-reaching results of the observation by Pavlov that the utmost care must be exercised when studying the conditioned reflexes to exclude all stimuli however trivial they may appear, except the one under consideration.

Under the most favourable conditions, however, it has up to the present been usual to find a considerable unavoidable margin of variation in the results of many physiological experiments. By regarding these provisionally as 'chance' variations, considerable help may be obtained by the application of the theory of errors, based on the theory of probability. In reality this is an empirical method of which Poincaré has said that 'everybody firmly believes in it, because mathematicians imagine that it is a fact of observation, and observers that it is a theorem of mathematics,' but nevertheless, although it cannot, as seems sometimes to be assumed, be used to replace accurate observation, it does enable a result to be brought out which might otherwise be obscured by small variations beyond our control. Research by such statistical methods provides a useful method of investigation, as, for instance, in the study of the toxic or other action of drugs, the data of the œstrus cycle, &c. An elementary deduction which can be drawn from the consideration of these facts is that, where only a few experiments of any kind are performed, important conclusions cannot be drawn unless it can be shown that the conditions are so controlled, and the accuracy of the actual observations so high that the sum of the individual 'chance' variations must be small. Observation of this precaution would, in my opinion, reduce the bulk of contemporary physiological literature very materially, with a corresponding improvement in its quality.

Lastly, as a means for evolving generalisations out of experimental data, and of bringing these into relation with the generalisations of other branches of science, the use of mathematics is incontestable. One need only mention as examples the fresh outlook which has been provided for further investigation by the exact study of the data relative to the segregation and recombination of hereditary factors, the beautiful investigations of L. J. Henderson on the equilibria in the blood, the theoretical study of the phenomena of excitation, the employment of thermo-dynamics and the numerous other applications of physico-chemical theory.

Certain applications of physics to physiology are quite clear-cut and need no further comment; but in many respects conventional physics has for our purposes serious limitations, which the physiologist must try to make good by his own investigations. For instance, many hydrodynamical problems of a specialised kind are connected with the study of the circulation. The physical theory of the flow of homogeneous liquids in wide, rigid, unbranched tubes is fairly well established, though, I understand, somewhat abstruse. But when we come to study the physical aspects of a pulsatile flow of a heterogeneous mixture like blood along

tubes which are branched and of varying degrees of elasticity, of diameters which in the same system range from several centimetres down to a few microns, and these subject to variations, we can expect little help from orthodox physics, which is not in the habit of working with so many independent variables.

It follows that much of our physics, if it is worth calling that, must of necessity be empirical for the present. This is not a defect in physiology—it is a defect in physical knowledge.

Chemistry and physiology having both originally sprung from the art and practice of medicine, it is little matter for surprise that such a rich harvest has been reaped by their reunion in the form of biochemistry. Although these developments were foreshadowed by the intuition, if not by the actual achievements, of the iatro-chemists of the sixteenth century, little advance was possible until chemistry had, by separation from medicine, established its position as an independent science. So that it was not until about 1840 that organic chemistry and biochemistry were able, chiefly owing to the inspiration of Liebig, to make rapid progress, at least on the Continent. There is probably no branch of chemistry that is entirely without interest to physiology, but of course preference must always be given to organic and physical chemistry. It is significant that at the present time a steadily increasing number of young highly trained organic chemists consider it worth their while to turn to biochemistry; their welcome entry into our ranks gives us fresh hope and faith in our future, as well as in theirs. Already one can point to many achievements of the organic chemist applying himself to our problems, the work of Fischer on the carbohydrates, purine bodies and proteins and amino-acids, the more recent work on adrenaline, the identification of carnosine, glutathione, the structure of thyroxine and the natural bases, of which histamine threatens to rival or even to eclipse lactic acid in its importance to the physiologist. As is usually the case, rapid developments in biochemistry have followed improvements of technique; the advances in micro-methods of analysis, without which insulin would probably not have been discovered, or the constitution of thyroxin made known, have played a very important part; the same applies to the whole subject of physical chemistry, much of which, like colloid chemistry and the theories of buffer action, has been built up in response to biochemical requirements. Since the central problems of biochemistry are dynamical, most of its subject-matter must be treated from that standpoint, and here again the debt to physical chemistry must be recognised, particularly in regard to the study of enzyme action, and more recently of interfacial and membrane equilibria, of the molecular structure of surfaces, and of the phenomena of activation and the thermodynamics of oxidation-reduction phenomena.

Whether a biochemist should be primarily a chemist or a biologist is a question which has been much debated in private, though little in public. Personally I see no reason why he should not be both. If he must have one label, it is better that of the chemist, provided always that the biochemist works in the closest possible association with the physiologist. This is most essential if both are not to be deprived of much valuable interchange of ideas and, on a lower plane, of materials and apparatus.

In fact, I am convinced that within the limits of administrative possibility the greater the variety of workers brought together the better the results.

So much for the exact sciences. Their value to physiology is immense. They help us to interpret phenomena, but not to predict. In a word physiology is something more than biochemistry and biophysics; it is, and will always remain, a biological subject.

As its nearest neighbour among the biological sciences, zoology should have the closest relations with physiology, yet it is curious that during several decades, for reasons which need not now be discussed, these two subjects were as the poles apart. The newly disinterred subject of comparative physiology, however, bears witness to a returning interest of zoologists in the experimental study of function as against mere morphological classification, as well as of physiologists in comparative function as a valuable means of throwing light on their own special problems. For there can surely be no more fruitful means of studying that response to altered conditions which we know as structural adaptation, and which we consider as only a special case of response to a stimulus, than the study by physiological methods of those examples of homology and analogy with which zoological science can so abundantly supply us.

With the science of botany, except in its most general principles, physiology has a less direct connexion, though here too the demonstration of fundamental points of resemblance in the metabolism of plants and animals, and the fact of the mutual dependence of the animal and vegetable kingdoms on each other, reminds us that we cannot afford to ignore the physiology of any living thing. Nor, in this connexion, should we forget that many valuable suggestions have arisen from plant physiology—the discovery of the cell, of Brownian movement, of osmotic pressure, and the notion of the storage of food materials, for instance.

The relation of anatomy to physiology can best be understood if we recall the fact that when the time was ripe physiology separated off from anatomy, taking with it all those dynamic problems which concerned function, and leaving anatomy literally little but the dry bones. The stationary condition of anatomy during the last decades of the nineteenth century was similar to that of zoology, and indeed had similar causes, and was little relieved by the subsequent incorporation of anthropology and embryology. Histology had in most countries remained with anatomy, and had for the most part been content, like it, merely to describe the structure of preserved dead things. In Britain, it is true, histology had until quite recently everywhere remained with physiology, and had perhaps fared no better, for although the British, like their Continental friends, did 'nothing in particular,' they did not do it very well, for we must admit that histology had degenerated into a merely descriptive subject, supplemented by training in a useful technique, and by the identification of specimens. Nevertheless, there were rays of hope, and occasional hints, as in Bowman's researches on the kidney, Hardy's study of the structure of protoplasm, Langley's investigation of the changes in glands during secretion, or more recently Herring's careful study of the pituitary body, that the problems of function had not been entirely lost sight of, and that the large mass of histological information which had

been collected might become valuable if only the fundamental question as to the reality of the structures described could be settled.

At the present time some English schools have followed the American and Continental practice, and handed histology over to anatomy, and though I am personally not at all convinced of the justification of this step, yet in view of the indications of quickening in the subject of anatomy during the past two decades, it no doubt is best to suspend judgment as to the ultimate result of the transfer. The portents of the approach of a more live and scientific type of anatomy, of an anatomy of a kind far more useful to physiology and to medicine, are many. The study of the relations of organs in the living body, of the functional significance of structure, the newer experimental histology, as typified by studies with ultra-violet illumination, ultra-microscopy, micro-dissection of live cells, tissue culture, micro-chemistry and the remarkable development of experimental embryology, bring to the physiologist joy and hope, and the conviction that the artificial line of demarcation between anatomy and physiology will happily soon be a thing of the past.

The relations of anatomy and physiology to pathology are, or should be, as close as those with each other. When the separation of physiology from anatomy took place many methods and problems which rightly belonged to pathology went with it—such problems of nutrition as inanition, rickets, diabetes, ketosis and acidosis, or jaundice, and of the circulation as heart-block, fibrillation, and so forth. These and many other problems were studied in the physiological laboratory by methods which physiology had come jealously to claim as its own ; the dead study of anatomy led to a pathology of the dead in preference to that of the living, and the euphemism so common in the wards 'when this case comes to the pathologist,' meaning 'when this patient is dead,' is significant of this state of affairs. Yet it must be quite apparent that pathology and medical science can only take as their starting-point the study of the normal individual as presented by physiology.

Instead of this, the experimental side of pathology has up to the present been almost entirely directed to the study of bacteriology, which, though well enough in its way, is too narrow and superficial, because it gives insufficient information as to the relation between bacteria, their products and the tissue cells on which either infection or immunity can be explained. Now that the subject of physiology is so far advanced, the time is ripe, if not overdue, I think, for the pathologist to come into his own, and for the subject of experimental pathology, with ramifications similar to those of physiology, to attract some of the best brains in the world of biological workers. And, if the knowledge of service rendered to their fellows be regarded as payment, they will be well paid.

The subject of psychology was until recently included at the British Association as a sub-section of physiology. As a science psychology must always retain the closest links with physiology, and I think that in the future these links will be strengthened rather than weakened. The researches of Pavlov on the conditioned reflexes will undoubtedly revolutionise the study of physiological psychology, and I need offer no further comment on their scientific excellence, or on the general approval they have won, beyond reminding you that they have already been condemned by Mr. Bernard Shaw.

I have, I hope, said enough to lend emphasis to my principal point, which is that the subject of physiology has the most intimate and vital contact with all biological subjects, with the fundamental sciences, and with medicine. It is, in fact, one of the best possible illustrations of Herbert Spencer's idea that 'the sciences are arts to one another.' It has often been said that science knows no frontiers and no nationalities. If we apply this a little nearer home we shall all look forward to the day when departments will merely indicate administrative boundaries and not intellectual compartments. In the meantime it is to be hoped that increasing numbers of young people specially trained in other sciences will think it worth their while to try to understand what physiology is and what it is striving for, and that they will come to our aid with their own special implements and standpoints.

Philosophical Position.

Although the application of those sciences which are called 'exact' is of immense value to physiology, we must be under no misapprehension as to their real relation, which is merely that they enable the phenomena of life to be described more accurately. They in no way furnish an explanation of those phenomena or enable us, without direct reference to physiological facts, to forecast them. The so-called exact sciences appear to be so because of the simplifications of which they are capable, by reason of which problems can readily be formulated and attacked. Disturbing conditions can provisionally be ignored or allowed for, and a first approximation reached which can be corrected later. In biology this can less readily be done. It is the failure to appreciate this elementary fact which leads some of those trained only in the methods of the exact sciences into the most palpable and unpardonable blunders when they attack biological problems. To take a simple illustration, no amount of pure physics, chemistry and mathematics would have enabled the intricate and beautiful physico-chemical adaptations which have been shown by L. J. Henderson to happen in blood, to have been predicted, because these adaptations depend, among other things, on the presence of membranes round the red cells, fashioned by the living cells and having properties incapable of prediction. The investigation of the equilibria themselves, in their physiological significance, was a necessary preliminary to the introduction of physico-chemical theory. When these phenomena, and deductions from them, became known, it was possible for the physical chemist to step in, apply the appropriate theories, and thus enable the phenomena to be more accurately described in his own language.

But the fact remains that this description turns entirely on the postulated physico-chemical properties of the membranes as deduced from their actual behaviour under given conditions in what are in reality physiological experiments. It brings us no nearer to an explanation, perhaps, but it certainly does enable us to link up some of the phenomena of life with phenomena in the non-living, and so to describe them in terms which we think we understand better, because for some reason we regard physics and chemistry as more fundamental sciences than biology. Whether they are really more exact, however, is a point which might be debated.

The process of application of the exact sciences to physiology consists in reality of studying the phenomena themselves and then adopting the most plausible explanation capable of formulation in terms of the exact science. There is no other way. But let us be under no illusion about finding final explanations of what life is by this or any other methods.

The enormously rapid developments of physics in recent years strike the uninitiated onlooker dumb with an almost religious awe. Matter and energy are as fleeting as time, and the ingenuity of man has spanned the mighty extent of the known universe. Matter, energy, time and space are in the melting-pot, and out of it will come we know not what of strange relations of one to another. Of one thing we may be sure—that no final explanation will follow. Lines of separation previously held to be rigid will probably fade away, and there will be found to be a continuity between matter and energy, between living and non-living, between the conscious and the unconscious. But since philosophy cannot arrive at an explanation of the nature of human understanding, the great mystery of the origin, nature and purpose of life will, I think, always remain to tease, stimulate or humiliate us.

Each must decide for himself what view he takes, and as many of our religious and philosophical beliefs are no doubt unconscious wish-fulfilments, I feel that it ultimately amounts to our decisions being dependent upon our individual temperaments, or, in other words, on our personal physiological make-up.

It was pointed out long ago by Claude Bernard that all *a priori* definitions of life, like those of time, space or matter, are futile, since they usually themselves imply the thing defined. Let us take one or two famous definitions of life as examples. Bichat in 1818 defined life as 'the sum total of those functions which resist death.' Here we have two opposed ideas, life and death. 'All that lives will die; all that is dead has lived.' For Bichat life is a struggle of the living thing against an environment which seeks to destroy it, but it is clear that the idea of life as opposed to death is implicit in the definition. This idea of an internal teleological principle, of entelechy, runs through all biological writings back to Aristotle, with whom we believe it to have originated. The amœba which encysts itself does so in order to defy adverse conditions in its environment. The 'calculating intelligence' postulated by Kant directs this response.

Another definition of life which has been much favoured of late is the mechanistic one in various forms; 'life is a special activity of organised things.' Here again the definition implies the idea itself. The possession and maintenance of a definite structure cannot any longer be held to be an outstanding feature of living matter as commonly understood, for recent researches in physics show us that, although electrons may come and go, the atomic structure of matter is relatively stable, even though under particular circumstances mutations may occur. Nevertheless the view of life as a mechanism created by and entirely dependent upon its environment gained strength owing to the developments in other sciences, particularly by reason of the synthesis of organic compounds, the principle of the conservation of energy and the introduction of the Darwinian theory of evolution. According to this view, a revival of that of Empedocles,

teleological manifestations are accidental. As that thoughtful writer Hjort remarks, however: 'When we, as human beings, call a thing accidental, it only means that we give up the hope of understanding it. . . .' 'In the physical sciences those factors are termed accidental which we voluntarily disregard in the course of an investigation, or which we find we have omitted to notice.' Kant, however, in his Kritik of Judgment calls the teleological 'the link whereby our understanding can alone be supposed to find any agreement between the laws of nature and our own power of judgment.'

Mechanistic interpretations tend in the long run to become arrogant and superficial, as vitalistic ones predispose to scientific nihilism. For, while it is inconceivable that living things do not obey the laws of nature, yet it is equally unthinkable that a chance encounter of physico-chemical phenomena can be the explanation of their existence. This being so, how can we, in Kant's words, 'arrive at an understanding of nature'?

It seems clearly impossible to harmonise or to decide between these opposed views of the nature of life, and I do not think any final conclusion to be possible or even necessary. To quote Hjort once more, 'Philosophy has no other starting point than a problem, and the current results of scientific research; it never leads to any absolute conclusion. It grows with the science of nature, since in reality it comprises the most general results of that science and comprises nothing more. It does not explain the nature of the human understanding, and provides no means of getting behind the understanding itself . . . the existence of which is the first and necessary condition for the existence of science at all.'

Physiologists, in attempting to know what life is, have in my opinion attempted too much, and I think that a new standpoint is essential. One of the greatest of contemporary thinkers, L. J. Henderson, has recently submitted an argument with which I venture humbly to agree. The idea of adaptation, urged by Claude Bernard, should be adopted by physiology as its basal principle, as the chemist accepts the conservation of matter or the physicist the conservation of energy. We need not seek to know why it is so: that is the province of the philosopher; all our experience tells us that it is so. It is not a definition of what life is, but a brief statement of its way, which is valuable, stimulating and true. But we must treat the organism and its environment as one if we are to gain a proper insight into the adaptations manifested by the former. Life is conserved by adaptation, and I venture to think that this conception will be useful alike to general biology, to physiology and perhaps most of all to pathology. For there is no fact in biology, pathology or therapeutics which may not profitably be viewed from this fundamental physiological standpoint. An essentially similar standpoint has been reached by Haldane, who says: 'We can reach no other conclusion than that it is the very conceptions of matter and energy, of physical and chemical structure and its changes, that are at fault, and that we are in the presence of phenomena where these conceptions, so successfully applied in our interpretation of the organic world, fail us.' It is the concern of physiology to study the normal functions, and here the normal must be regarded as a statistical group. For particular purposes it is convenient to consider normals as of fixed value; thus the normal man has a body temperature of 37.5° C.,

a pulse rate of 70, a systolic arterial pressure of 120 mm. Hg, a red cell count of 5,000,000 per cubic mm. or an alveolar carbon dioxide pressure of 40 mm. Hg, &c., and we can investigate the means by which this constancy is reached. But for other purposes it is equally convenient to regard each of these in turn as variable, to study its variations and find how they are produced. When we do so we find with increasing clearness the more deeply the subject is investigated, that the variability and the constancy are closely related, the fixed value of one thing being due to the interplay of the variables of others. Thus the constancy of the alveolar CO_2 pressure may be regarded as due to the interaction of such variables as hydrogen ion concentration of blood, body temperature, ventilation rate, oxygen pressure, &c., by which a state of equilibrium is maintained.

We have in the study of physiology many beautiful examples of this closely woven texture of interdependent phenomena. Modify any condition concerning any one of them, and you at once set the machinery moving in such a way as to counteract what you have done. And this is not what life is but what it does, which distinguishes it—it adjusts the organism to its environment.

There is a striking though superficial resemblance between this principle of biological adaptation and the principle of Le Chatelier of 'the opposition of a reaction to further change' which is expressed 'when any system is in a state of physical or chemical equilibrium, a change in one of the factors of equilibrium will cause a reverse change within the system.'

In living things, however, as Donnan has remarked, 'the activities, and indeed the very existence, of a living organism depend on its continuous utilisation of an environment that is not in thermodynamic equilibrium. A living organism is a consumer and transformer of external free energy, and environmental equilibrium means non-activity and eventual death.' Nevertheless, as Claude Bernard believed, and as Henderson has strikingly illustrated, the internal environment is maintained very constant in certain respects, and this constancy is the outcome of special activities which characterise life.

Glancing now towards the future, what may we say represents in a few words the trend of modern physiology? In many ways a great future lies before it. Utilising the other sciences as its tools and itself reacting powerfully on them, we can confidently predict progress to undreamt-of heights, an enormous development of experimental pathology and medicine, and far-reaching effects on economic and sociological conditions. Yet, implicit in these very potentialities, there is another and a gloomier side to the picture. The rapidly accumulating wealth of detailed knowledge and of special technique demands an increased specialisation; unless there is a periodic intellectual stocktaking there must inevitably be a loss of perspective and of grasp of great general principles. But how can this stocktaking be done? Can team work ever reach that harmony of action which distinguishes the individual? Any scientific subject is capable of indefinite expansion, and with the biological sciences it is hard to foresee what the ultimate end of *mere* expansion can be. How will scientific literature develop? Will there have to be abstracts of abstract journals and reviews of reviews? Will the subdivision of the subject necessitate in the long run the creation of lectureships or professorships

to deal, for example, with the special physical chemistry of heterogeneous equilibria in biological systems, with intermediary metabolism, with the problems of hæmodynamics, or growth, or reproduction ? If so, how will the results of their special investigations be brought to common ground if no great unifying principles come to light ? Can we expect that such unifying principles will appear : if they do not, will the progress of science be brought to an end by the accumulation of its own products ?

The establishment of special research professorships, however profitable in isolated cases, cannot in my opinion make good this growing specialisation, because it will tend to divorce research and teaching and place the teaching professor on a level of real or apparent inferiority. The idolisation of research for the sake of the advancement it brings is another of the dangers which threaten us. If there is one thing worse than 'a mediocrity who does no research' it is 'a mediocrity who does.' There are at the present time a large number of junior research posts available, but not enough well-trained people adequately to fill them. This is all to the good provided that those who on trial show no aptitude for the work can be ruthlessly eliminated. As they often cannot, there are in consequence a number of young people who drift from one research scholarship to another, perhaps not aimlessly, but with no better objective than the manufacture of papers designed to justify their employment. The hapless editors of each of the swelling tide of journals are coaxed, hoodwinked and, if necessary, bullied, to ensure that these papers see the light of day. In the fullness of time the list of short-time research posts is exhausted, and the young investigator must now either turn to some entirely different occupation or else, as one of my friends expressed it, 'subside into a professorial chair' for which, incidentally, he is probably entirely unfitted. The pursuit of science is nowadays, perhaps unfortunately, a career, and one in which moreover it pays to advertise. Science, we are often told, is the cream of civilisation. If we believe this let us use all our endeavours to ensure that it be not a whipped cream, specious, puffed up with wind, and presenting a fictitious appearance of solidity.

SECTION J.—PSYCHOLOGY.

THE NATURE OF SKILL.

ADDRESS BY
PROF. T. H. PEAR, M.A., B.Sc.,
PRESIDENT OF THE SECTION.

Preparing the presidential address to a section in the British Association offers special pleasures and perplexities. The subject may be partly familiar to many, almost strange to others. Knowledge of this is apt to produce in the writer an inner conflict. He tries to be clear to specialists in his own subject and to those from other sections. Seeing the two stools only too well he falls heavily between them.

The present theme, 'The Nature of Skill,' is no exception. Most persons recognise skill when they see it, yet the terms with which they try to analyse it are often lamentably vague and incommunicable.

The Concept of Skill.

The word 'skill' is used in many ways. It is therefore reasonable that for scientific purposes its connotation shall be slightly limited. The following is proposed as a definition : *Skill is an integration of well-adjusted performances.*

In such a terse statement all the words need explanation and illustration. First, it is useful to contrast skills which come within the range of this definition with that type of adjustment which is a collection of mere habits.

The qualification 'mere' is important. Habit, in some recent writings, has included virtues, vices, thought, will, sensory discrimination, art, intelligence, routine, plasticity, and sensitive response. This is a concomitant (one hopes, not inevitable) of abandoning the word instinct.

I would suggest that the outstanding feature of habit is its *specificity.* The experimental work upon transfer of training has made a belief in general habits untenable.

The Definition of Habit.

A habit may be defined as an acquired specific response to a specific situation. As soon as we cease to respond specifically, or the situation loses its specific character, our behaviour ceases to be habitual.

Skill is dependent upon habit, but not completely. The present suggestion is that, treating the term skill with respect, we should apply it only to the higher types of well-adjusted performance.

A Misuse of the Term 'Skilled.'

It is undesirable to use the word 'skilled' to denote, not the workers' performance, but the potential work waiting to be done. I am aware that

this is customary in industry. Hence this stricture. Its use hampers analysis and clouds any presentation of the problems. For since there is seldom only one way of doing a skilled job, the events occurring in the bodies and minds of different performers will not be alike.

Possibly, in some metaphysical sense, a job may exist when nobody is doing it. Yet, especially since May 1, 1926, there is now little enthusiasm for this type of industrial subjective idealism.

To talk or write about the 'skilled job' rather than the skilled man, and about the 'skilled trade' as if a trade were a unit, encourages unthinking people to believe (*a*) that work exists when it is not being done, and (*b*) that this non-existent entity 'belongs' to somebody. Both errors are costly and stupid.

Skill and Low-Grade Collections of Habits.

Some so-called skills are a fortuitous concourse of habits. And many of these are bad. Often no single habit in the number is well adapted to the task, and the whole collection is only a makeshift, though a makeshift for the whole life of its possessor. Contrast this with the higher skills; integrations, not mere collections of responses, and not necessarily of habits only. Then to describe as skill some industrial occupations, and some forms of domestic service in England, would be flattery.

One of the first analyses of skill was made by Mr. Frank B. Gilbreth. Studying a bricklayer, he found that his eighteen movements in laying a brick could be reduced to five. One may conclude, therefore, that the original performance which he analysed could be called skilled only in the popular sense.

Skill, Capacity and Ability.

Skill must be distinguished from *capacity* and *ability.* To possess a delicately discriminative inner ear and muscles under perfect control is to have capacity for musical performance. Obviously, such gifts may exist in a person who as yet has shown no musical ability. For he proves his ability to do a thing by doing it. Even by failing he does not necessarily demonstrate his lack of capacity. For if untaught he usually will have tried to do it in the wrong way.

Skill is clearly ability, but ability to do a relatively complicated series of actions easily and well. A man who can run need not be skilled in running. But if he has learnt to move his legs well, to regulate his breathing, to sprint at a particular point or moment, to estimate the time in which it is wise to run a particular lap, to adapt himself to different tracks, different lengths of race, different classes of competition, and different competitors, he possesses skill in running races.

Skill, therefore, implies discrimination of the situation and graduation of the response. But to this should be added what I suggest as the essential characteristic of skill—the ability to *integrate* responses,[1] and in

[1] *Cf.* the description and photographs of the modern skilled high-jumper in Prof. A. V. Hill's ***Living Machinery,*** London, 1927, pp. 202 and 208.

the highest skills to substitute, instantaneously if necessary, one type of integrated response for another.

In man, this integration of well-adjusted performances is acquired and fused with natural aptitude, the nature of which will be discussed in a moment.

Skill and Reflex Action.

Those reflex mechanisms which contribute to balance, to the maintenance of posture, and to the efficient co-ordination of action are an important basis of skill. In this sphere we honour the famous contributions of Sherrington, Head, Magnus, and Pavlov, to whose great work, *Conditioned Reflexes*,[2] we stand too near to see it in perspective.

Can the physiologist regard skill as entirely an integration of conditioned reflexes ? Eventually, perhaps. More than that we cannot say. We are warned not to exaggerate their interpretation.

An impressive fact is that to ensure the certain conditioning of a reflex the control of external surroundings must be complete. The necessity, for example, of a sound-proof laboratory, of the absence of the experimenter, to say nothing of spectators, emphasises the specificity both of situation and response. Skill, on the other hand, typically shows itself in the rapid adjustment to a changing environment and to unforeseen conditions.

It seems premature to speculate whether the ' conditioned response ' formula, valuable as it is, will prove adequate to explain skill as well as habit. Yet—to pass from conditioned to unconditioned or 'racial' reflexes—there seems to be no doubt that neuro-muscular patterns controlling them can be inherited. But here the relation of inherited to acquired ability is complex and subtle. Such a fundamental activity as walking is affected by race, education, dress, profession and transient fashion. Even if we confine our consideration to a dominantly reflex event such as the assumption and maintenance of posture, it is clear that in ourselves the matter may be partly controlled by consciousness. By taking thought we can improve balance, assume different types of balance, even plan balances in advance.

Skill and Instinct.

Comparison of human and animal behaviour has always offered great attractions—and risks—to members of the British Association. Yet I believe that the present comparison is not difficult. While many animals inherit high-grade skills, man does not. Birds inherit skill in nest-building, the kingfisher making one type, the swallow another, and moreover, selecting different materials.

At birth, man is spectacularly unskilled. The skills which he subsequently acquires are almost entirely determined by his social and material environment. But he compensates for his start from scratch by the number and complexity of the skills which he soon acquires. And of these, language, whose raw material is speech-habits, is an amazing example.

[2] Oxford, 1927.

An animal may blend acquired with inherited skill. The song-thrush may learn deftly to break snail-shells upon a stone. Yet in animals the modification of such inherited skill is relatively small, compared with improvements made by man.

Human instincts (inherited, general responses to general situations, characteristic of the species) probably play unimportant rôles in the final polished expression of human skill. Yet they may powerfully impel a person to strive to acquire a skill against material and human obstacles. Tendencies to self-assertion and self-display, pugnacity, gregariousness, and desire to win the regard of the opposite sex are such forces. Whether they be regarded as integrations of reflexes or instincts happens to matter little in the present connexion.

Skill and Habit.

That a congeries of habits ought not to be dignified by the name skill has already been suggested. Naturally, habits are important components of any skill. But in skill worth the name they are of a special kind. They ensure adequate adaptation. Moreover, especially if the conditions demanding adaptation are complicated and numerous, the habitual movements interact so that the whole skilled action is more than the sum of its parts. This may be illustrated from lawn tennis. A player may acquire useful habits, such as gripping the racket correctly and placing his feet and body so as to get his weight behind the drive. But if a return has to be made from outside the side-line, the orthodox position of the feet and the body must be modified to accelerate the quick assumption of another position on the court, and another balance. For the ball has usually been placed there to get him out of position for the next return.

Skill, as distinct from habit, involves the ability to be aware of, and to correct, imperfect or faulty adjustment. This is implied, for example, in a surgeon's or automobile driver's skill. While skill employs habits, it can immediately interfere with, break up or modify any combination of them. This makes it easier to study in its lower than in its higher forms. But this fact should not encourage students of skill to draw too wide conclusions from the observation of its humbler components. It would be difficult to infer the properties of alcohol from the most complete and rigidly scientific study of charcoal.

Patterning a Characteristic of Skill.

The term 'pattern' has appeared frequently in recent psychological writings. But its meanings have been different and not easy to equate. It will be used here simply and objectively to mean an arrangement of human movements in time and space which shows *integrated order.*

Always in theory, and often in practice, such a pattern could be recorded, *e.g.* by Gilbreth's moving, interrupted light fastened to any salient part of the body. Such a pattern could be left by the shoes of a dancer, if they were suitably treated. The ice and the snow record beautifully some movements of the skater and the ski-runner. But they receive a trace only of one part of the body. Usually, however, many other parts are simultaneously moving in unison, in harmony, perhaps

even in counterpoint. All these spatial and temporal characteristics of pattern could be recorded. But equally important would be the delicate variations in force, corresponding to accent.

This integration of the part-actions into wholes usually expresses the individuality of the performer. It is unlikely, for example, that the separate steps of a dance are ever fused into a whole without being changed.

Skill and Awareness.

Unless and until a highly skilled action has become really automatic, the performer is aware of its integral character. This awareness, unclear though it may be, determines the character of the part-actions. Examples are stress, accent and intonation in speech. As the sentence is initiated the whole, of which the speaker is aware, determines the parts. To speak a foreign language well, one must raise and lower the voice at points quite different from those which would receive the stress in one's own tongue. To acquire such skill the learner must attend not so much to the single words as to the whole sentence.

This patterning, which dominates corresponding bodily and mental events, acts upon reflex, instinctive and habitual mechanisms. When it employs habits it usually transmutes them into actions less fixed and more adapted to the situation.

'Knack.'

A most interesting example of patterning in skill is 'knack.' It would be unprofitable to quarrel about the exact meaning to be attached to a popular word, but the definition of Mr. Vivian Caulfeild in his book 'How to Ski '[3] promises to be as useful in theory as it is in practice.

He defines knack as 'the ability to perform easily a rapid and accurate co-ordinated movement of a number of muscles,' and continues :

> If this movement is an unaccustomed one the ability to perform it properly is only attainable by long practice.
>
> The action of throwing, for instance, requires knack. It is this which makes it so difficult to learn to throw with the left hand, even though one already has the ability to move the left arm with quite sufficient strength and speed, and knows not only how the movement should be made, but even *how it feels*, to make it with the other hand. Writing is another excellent example of knack.
>
> In ski-running nothing which can strictly be called knack comes into play. In this sport the *voluntary* muscular movements (as distinguished from the involuntary ones used in keeping the balance) are neither complicated nor unusual, and, except in jumping, they need seldom be rapid. Any difficulty in learning them is due partly to the disturbing effect on one's clear-headedness of the speed at which one is travelling, and partly to the fact that some of the movements, though simple in themselves, are almost the reverse of those one's natural instinct would prompt one to make in the circumstances. This difficulty, of course, diminishes with practice, but an effort of will goes just as far as, or even farther than, practice towards over-

[3] London, 1924, pp. 10–12.

coming it. Were it not for this difficulty a man who had been told the right way to perform the various manœuvres employed in ski-ing might very well do them fairly correctly the first time he tried (as many people actually do), while no amount of strength, activity, intelligence or confidence would enable him, if right-handed, to throw or write properly with his left hand without long practice.

Knack, therefore, may be regarded as the ability to impose upon one's behaviour very rapidly a special well-adapted pattern.

In throwing a ball, it has been demonstrated[4] that a number of muscle-groups must co-operate, simultaneously and successively, *very rapidly*. The succession of events which make up the performance is suddenly accelerated. The leisured semibreves and minims give place to tense semiquavers and demisemiquavers; the wide folds in the time-fabric ruck into pleats.

The Relation of Skill to Natural Aptitude.

If such analysis of skill be admissible as a foundation for investigation, aptitude for a particular form of skill may be regarded as based upon well-marked and well-co-ordinated reflexes, instinctive tendencies suitable to the task, adapted habits, and the power, or maybe powers, of patterning.

This power might be partly innate, partly acquired. To produce new patterns may be a mark of genius in skill. The loss of patterning-power through fear, fatigue, cerebral injury, drugs or unusual physiological happenings offers a fascinating series of problems, especially in their relation to individual differences.

Of high-grade skill there are two types:

(*a*) Unoriginal. This skill may effect very complex and satisfactory adjustment. It characterises some—perhaps most—processes in industry, and many in the army and navy, where predictability of action is a *sine qua non*, and originality may be unpopular, inconvenient or dangerous.

(*b*) Skill containing something personal, creative, unique and difficult or impossible to copy.

Psychologically interesting is the adherence of different nations, different strata of society, and of the same strata at different times to certain patterns in skill. The antagonism of lovers of the original waltz to those of the newer kind, and of these latter, one reads, towards those of the newest, is as instructive as the pained aloofness and amused indifference in the mutual regard of the two schools of figure-skating.

The Interference of Skill-Patterns.

Clumsiness, arising in a formerly skilled action, is sometimes due to the interference of a new recently learnt pattern with an older one, to which it is partly similar but to which some of its constituents are antagonistic. A superlatively skilled person may establish the independent status of the two patterns. But usually, unless such a separation be consciously effected, they will interfere.

An example may be taken from ski-ing. In making a certain 'Christiania swing,' at one point the ski-er must lean away from the

[4] A. V. Hill, *op. cit.*, pp. 203 *ff.*

direction of the turn.[5] This is unwelcome to most beginners, as it may involve deliberately leaning down the hill. But it offers unique difficulties to any figure-skater who has consciously perfected the habit of leaning automatically and invariably *towards* the turn. It is possible, however, consciously to separate, to recognise and to understand the two requirements. Thus a person who skis and skates regularly may effect an integration which comprises both turns.

A master of only one class of movement-patterns, however perfect, in a certain sphere of activity may in one sense be less skilled than another who disposes of several. Yet the first, because of his excellent expression of that one pattern, may be popularly regarded as the more skilled. It might be said that his *intensive* skill is greater, his *extensive* skill less than the other's.

And here, remembering the complications in any discussion of a related subject, intelligence, we may ask: 'Do special skills exist in a person alongside a general skill?' I have discussed this subject, and researches which bear upon it, elsewhere.[6] It is too complicated to be developed here. But there is reason to believe that though the extensively skilled person may be jack of all trades and master of none, his skill in some directions might be brought to a higher level by good teaching and intelligent learning, events which are becoming commoner every day.

'Propria' and 'Accidents' of Skill.

(*a*) *In sport.*—One may pertinently inquire if some of the features of ordinary sport-skills are essential or accidental. Borrowing terms from logic, we may inquire if skill has its *propria* and its *accidents*.

He who would answer this should purge himself of local and topical prejudices. Many persons assume that skill must consist in the delicate co-ordination of hand and eye and in the timing of complex actions to coincide with a momentary combination of external events. Both these gifts are often indispensable in dealing with a moving ball. But the hurling of missiles is not the only skill to which man aspires. Certain skills are proudly possessed by the blind. Delicate timing enters hardly at all into many kinds of postural skill, and is seldom necessary for industrial tasks. So probably those subjects which an Englishman would naturally want to study, moving-ball games, should be put late in the programme. More may be hoped at present from the study of postural skills, depending little upon the athlete's 'eye.' Such are swimming, gymnastics, ski-ing, skating, dancing, and eurhythmics.

Sometimes competition in skill is a proprium, sometimes not.[7] The most obvious kind of competition is *destructive*, where A tries to spoil the effect of B's skill, or to prevent it, as in boxing, fencing, football and hockey. Cricket and tennis involve semi-destructive competition, through prohibitions of space. Your cross-court shot may merely amuse your opponent, but at least it lived from your racket to the net.

In many sports the competition is non-destructive. The performances may even be successive, with every chance for the competitor to do his

[5] Caulfeild, *op. cit.*, pp. 178 *ff.*

[6] *Skill in Work and Play.* London, 1924, pp. 22 *ff.*

[7] *Cf.* an article 'Physical Culture in Germany,' *Manchester Guardian*, July 24, 1928.

best. And for this reason I believe they will the sooner repay study. Smith's six-foot high-jump can never be spoiled by Jones collaring him low at the take-off.

These distinctions may be obvious. But I have never seen them made in scientific discussions of skill. A little less obvious, perhaps, is the thought that different types of competition are excelled in by persons of different temperaments. Too much of the fighter's spirit and too little of the artist's and thinker's may lose many games.

In many skills emotion is an 'accident.' Obviously a player should keep his head. But coolness may be but indirectly related to skill. Some play better when keyed up, fearing nerves less than stodginess; some wilt at the thought of spectators; others admit, even seek, the inspiration of a friendly and understanding crowd.

Though emotion as an accidental factor may help or hinder the expression of skill, yet in music and acting it may blend with and form an integral part of the expression. Actors, for example, sometimes genuinely feel the emotion which they are portraying.[8]

To discuss the problem of what is loosely called 'nerve' in sport is impossible here.

(*b*) *In work*.—In industry many skilled actions are performed in unvaried conditions, with little or no emotion. Important exceptions exist which the public often finds it convenient to forget, as, for example, in coal-mining. However, it would not be surprising if the problems of skill in industry, complex though many of them are, proved to be easier than those of skill in sport.

Thus far an attempt has been made to filter the general concept of skill and to reject irrelevant meanings. In dealing with industrial skill I am indebted to an article by Miss Anna Bezanson.[9] She writes:

> Considering the glibness with which workmen are pigeon-holed as 'skilled,' 'semi-skilled,' and 'labourers' in many industries, it is surprising to find little definition of what constitutes skill or lack of skill. Everyone takes it for granted that precisely what he means is understood by referring to a workman as possessed of 'skill.'

We may utilise her collection of 'accidental' factors in industrial skill.

(1) *Accepting responsibility for many independent decisions*.—Though arriving at these decisions may involve skill, the acceptance of responsibility is due to other factors. When the acceptance is voluntary and congenial, these factors are dominating sentiments. In our country the more expensive systems of education successfully inculcate such a ready acceptance of responsibility. Sometimes, however, their pupils seem puzzled by the lack of a similar readiness in those who have been schooled more cheaply. Remedies for this will be gladly suggested by the teachers concerned. Smaller classes and larger playing fields come early on their lists.

(2) *Learning about the capabilities of materials*.—This involves the ordinary processes of acquiring knowledge. Muscular or kinæsthetic knowledge can only be obtained by doing. But with the progress of science it is every day easier to get from books knowledge which was

[8] *Cf.* W. James's chapter on the Emotions in his *Principles of Psychology*.
[9] *Quarterly Journal of Economics*, vol. xxxvi, 1921–2, pp. 626–45.

formerly locked up in the skill, real or alleged, of the professional. Cookery supplies many examples. The use of the weighing machine, the clock and the thermometer will supersede many rules of thumb. A child who has never made tea, but has read that the water poured on it should be boiling, knows better than many so-called skilled cooks.

(3) *The possession of judgment and knowledge concerning apparently 'outside' jobs* may rank a person as skilled in the primary occupation. In practice this may be important. Its theoretical meaning is simply that other things, including intensity, being equal, the greater the extensity of skill the better.

(4) *The ability to transfer knowledge and skill to a different industry and to different material.*—This raises the question of the relation between general and specific training in a pleasingly concrete and useful form. Actually it does so twice, once in the realm of knowledge and once in the realm of power. This will be discussed separately.

In industry a relatively new event may simplify the problem. Transference of a worker from one type of machine, or even from one type of industry, to another may be facilitated by deliberately designing the machine with that aim. A simple operation on a certain machine may nowadays be a unit in the production of quite different articles. So successful transference of skill may reflect credit not on the worker but on the machine designer and on the employer, an example of the portentous 'fractional distillation' of skill of which more will be said in the joint discussion with the Section of Economic Science on Monday morning, September 10.

A special instance of the interrelations between mental abilities (and bodily ones) is raised in the consideration of

(5) *Keenness of Perception.*—In theory, keenness of perception, which means fine sensory discrimination, *e.g.* of colours and tones, or perceptual discrimination, *e.g.* of shapes or patterns (not, of course, visual only), might or might not be linked to superlative skill. The method of correlation makes it possible to investigate this relationship. Pioneer work has already been done by Prof. Carl E. Seashore in the investigation of musical talent.[10] But, while it is unlikely that superlative skill will ever be found linked to subnormal discrimination, a high correlation between them cannot be assumed. And the correlation between sensory discrimination and general intelligence, though usually positive, is very low.[11]

(6) *Appreciation of the interrelation of factory processes.*—This involves intelligence rather than skill. But success in appreciating any relations may depend upon the way in which the data have been vouchsafed, and the extent to which they are obscured or illuminated by well-meant and enthusiastic 'explanation.' Explaining complex matters usually requires a skilled explainer. The skilled performer often does it especially badly.

A General Classification of Skills.

We may now attempt to classify skills, working upwards from the lowest type.

[10] *The Psychology of Musical Talent.* Boston, 1919.

[11] *Psychological Tests of Educable Capacity.* London, 1924. *Cf.* T. H. Pear, *Skill in Work and Play,* p. 23.

(1) *Collections of imperfectly adapted responses.*—This class includes much domestic work, the skill of most labourers and of workers in the semi-skilled trades. (It is true that some apparently simple tasks would be placed higher in the scale by an expert than by a scientific observer. It is equally true that an intensively skilled person may honestly over-estimate the absolute difficulty of his special skill.)

(2) *Perfectly adapted responses which do not exhibit personality.*—Such are the movements on parade of the perfectly drilled soldier. Military skill of this kind may be compared with the skill which would result in industry if a stereotyped series of actions, however efficient, were rigidly prescribed to the worker. Its advantages and defects are clear in military organisation. While the engineer, Mr. Frederick W. Taylor, tried to prevent 'soldiering' in the old American sense of that word, *i.e.* taking things easily, his own unmodified system would have produced soldiering of a modern type. This is recognised by many of his disciples.[12]

(3) *Responses resembling habits, but less specific and automatic.*—The importance and distinctive nature of such responses make one doubt the wisdom of classing them with habits. For habitual actions are inadequate to the situations which these others meet so very perfectly. Such responses are exemplified in sport when rapid, delicately effective complex adjustment is made towards the surface upon which the player is moving, *e.g.* wet and dry, hard and grass tennis courts, heavy and light football grounds, hard, soft, smooth and bumpy ice, and different hardnesses and elevations of snow-slopes. Such adjustments appear neither to the understanding external observer to be mechanical, nor subjectively to their performer to be unconscious.

This adaptation may be effected to conditions both outside and inside the body. A performer who is feeling ill, without decreasing control, may modify his movements so that less strain is put upon his muscles. A first-class automobile driver's adaptive behaviour in traffic makes the average motorist look like the bundle of habits which some pessimists declare man to be.

(4) *Responses like those in* (3), *but exhibiting in their totality a pattern characteristic of the individual.* This pattern may be original or unoriginal. A style which appears to the spectator to be unique may have been imparted by a teacher, though to it the pupil usually adds some personal touches.

Types (3) and (4) shade into each other, though in (4) an aspect implicit in (3) is emphasised. Probably these are in the minds of the protesters against the standardisation of industrial tasks.[13]

(5) *Creative Skill.*—This is no place to discuss the psychology of creative genius. But in this realm two kinds of creation may be distinguished. One is unconscious, or nearly so, as when a pioneer declares that his work finds its way out of him. Perhaps we may call it the artistic kind. The other results from deliberate analysis of earlier attempts,

[12] *Cf.* H. S. Person, 'Scientific Management.' *Report of First Triennial Congress of International Association for the Study of Human Relations in Industry*, July 1928, pp. 29–43 (Javastraat 66, The Hague).

[13] *Cf.* R. M. Fox, *The Triumphant Machine*, London, 1928, and list given in Pear, *Fitness for Work*, pp. 146–7.

satisfactory to the ordinary person (a host of problems are covered by the word 'complacency'[14]) but provoking to the genius.

Such analysis [15] may involve recall in memory (visual, muscular, and verbal) of various skilled feats, comparison and discrimination between them, selection of their relevant aspects, re-comparison with some aim in view, re-combination, and as a result, an unanalysed—perhaps unanalysable—polish which fuses the movements into a dazzling new unity.

This is inventive creation in skill resulting from analysis. It is seen and will be seen oftener in the world of play and art. It may increase in the world of industry, if industry desires and deserves it.

Intelligence, Intellect and Skill.

It is necessary to consider the place, in this scheme, of intelligence. What is its relation to skill ?

Writers have observed that it is easier to say who is intelligent than what is intelligence ; to agree upon what intelligence does than upon what it is. It seems possible for our purpose to describe intelligence by its fruits.

Acknowledging the value of certain recent writings which expound a different view, I still feel that for practical purposes intelligence may be described as the individual's capacity for adaptation to a new situation. Summarising Dr. P. B. Ballard's description,[16] we may say that intelligence is more fully manifested in the higher mental processes than in the lower. It is specially employed in situations which present points of novelty, *i.e.* the solution of problems. It is concerned more with the dissection, planning, and rearrangement of the data of experience than with the mere reception of impressions.

None of these assertions conflict with the possibility of a muscular or 'kinæsthetic' intelligence.[17]

Intelligence is clearly a capacity, not an ability nor a skill. In particular it is not the ability to learn, though the two may be closely related. A learner may supplement low intelligence by the skilful use of various devices and of good tutors. But to choose the devices, or the tutors who supply them, is often a sign of great intelligence, though not necessarily in the learner himself.

It may be useful to summarise the mental powers which operate alongside and are often confused with intelligence. It is not habit, knowledge, the ease which comes with practice, interest, capacity for taking pains or for application.[18]

Skill and Intellect.

The use to be proposed of the term intellect is less orthodox. Yet those who believe that the real meaning of a word necessarily exists in a dictionary may be reminded that dictionaries occasionally grow out of date.

14 *Cf.* Raup, *Complacency*, London, 1928.

15 It may follow the lines of analytic thinking in general. *Cf.* Pear, *British Journal of Psychology*, 1921, vol. xi., pp. 72–80.

16 *The New Examiner*, London, pp. 116 *ff.*

17 *Cf.* W. F. Dearborn, *Intelligence Tests*, Boston, 1928, pp. 112 *ff.*

18 Reasons for this fairly orthodox view are given in *Fitness for Work*, pp. 53 *ff.*

For Plato, as Prof. Spearman writes, intellect was the permanent mental power, intelligence the putting of this power into use. He adds that 'intellect,' which seems to be deliberately avoided by most writers, has always been essentially characterised by the power of abstraction.[19]

Yet the view seems justifiable that 'intellectual,' as used popularly nowadays, means 'able to express oneself in words' (spoken or written).

If its meaning be narrowed only slightly it would be very useful in the present connexion. The successful, deliberate use of any words to express oneself would be intellectual. Emitting words merely as speech-habits would not. This use, I submit, allows one to characterise a type very common in these days of universal reading and writing—the person who is definitely classed as intellectual though not necessarily highly intelligent.

Now many muscular knowledges differ from most other kinds in that they have almost no proper language. While it is manifestly possible to be intelligent about them, it is less easy to be intellectual. To describe skill, one's vocabulary often has to be collected in the grand-stand, the newspaper office, the study and the laboratory, rather than on the field of action. Perhaps because so many persons, skilled in certain directions, are inarticulate and almost mute, one tends to consider them as un-intellectual. Yet their type of muscular knowledge may possess few words, even if they searched for some. Often they would be the last persons to make such an effort.

In some spheres and by some exponents skill is becoming rapidly intellectualised. Yet the die-hards may take comfort in the vast tracts of untouched desert, both in their skills and in themselves.

Let us look at ourselves for a moment through the eyes of one who was in but not of our country. In *The Return*, Joseph Conrad pictures a man—

> 'whose clear pale face had under its commonplace refinement that . . . overbearing brutality which is given by the possession of only partly difficult accomplishments; by excelling in games. . . .'

May it be that such athletes have overcome only the non-intellectual difficulties in their game? To them it is just an occasion for the gleeful exertion of sheer strength, of low cunning, for the permissible indulgence of pugnacity and other simple instincts. One has met these men. The intellectual challenge, the exhilarating possibility that undreamed-of strokes, stances, breaks and swerves may be invented, are neither accepted nor comprehended. Yet ten years after an innovation has elbowed itself into the game's structure these men will be sternly teaching it.

To summarise this, a person skilled in work, art or sport, may not be intelligent or intellectual. Yet he may show one, two or all these qualities in a characteristic personal fusion. The thrice-blessed intelligent, skilled intellectual would use his intelligence upon his problems of behaviour. In this he would be helped by his intellect (*i.e.* by his power to recall, to select and to employ words) in formulating the problems, and in abstracting and expressing the general principles which he discovers or uses in solving them.

[19] *The Abilities of Man*, London, 1926, pp. 28 and 33.

When the knowledge which he seeks is available in the words of others, his intelligence and intellect will enable him more easily to understand and, if necessary, to paraphrase them. If he can visualise pictures, draw them (these two gifts not being necessarily interdependent), and abstract their salient features into diagrams, he will more easily communicate his meaning to certain readers, who in their turn may criticise, destructively and constructively. In this way he may bring the general principles derived from his special sphere alongside those obtained from other realms to which he may not have access. From such confrontations and intelligent comparisons he may enunciate new principles. These, by means of his skill, he can test in his own world of experience.

More suitable words than 'intellect' may be found for the mental power or group of powers described above. After much consideration I think that 'intellect' seems to do this best. Its adoption, however, suggests one disquieting possibility. It might encourage those who assume, tacitly or noisily, that conceptual intelligence and abstract thinking cannot be appraised or tested except by the use of words and numbers. Prof. W. F. Dearborn writes:

> The reason why it has been so difficult 'to devise tests of the non-verbal or "performance" type which will bring out intellectual differences much above the level of the average child of ten or a dozen years,' may be due to the fact that the verbalist and the scholastic have hitherto been the ones chiefly interested in the development of intelligence tests, and they have naturally chosen tests in the use of which their own intellectual powers will not suffer by comparison.[20]

He insists upon respect for the intelligence which thinks in terms of things rather than with the symbols for things.[21] As an illustration he quotes Prof. H. H. Turner's account of the way in which apparent changes in the wind's direction, observed in a boat 'putting about' on a river, suggested to Dr. Bradley the cause of the apparent changes in the direction of a star's light.[22]

It is useful to remind readers that abstract thinking is not confined to the use of auditory and visual symbols.[23] In so far as intelligence tests are limited to them, so far will the intelligence of an important section of the population be improperly gauged. For this reason I propose, for psychological purposes, the use of the word 'intellect' in the above-described way. It enables us to emphasise the fact that people who can do things may or may not be able to analyse and describe their performance. It would also remind the mute ones that their silence is not more golden than any other silence.

The Relation between Different Motor Abilities.

Tests of intelligence give results which correlate highly with each other. But there is no justified single concept enabling us to explain why some

[20] *Op. cit.*, pp. 109, 110.

[21] *Cf.* Mr. Aldous Huxley on the academic mind, in *Proper Studies*, London, 1927.

[22] E. Freundlich, *The Foundations of Einstein's Theory of Gravitation.* English translation by H. L. Brose. Introduction by H. H. Turner. Cambridge, 1920, pp. 11, 12.

[23] *Cf.* T. H. Pear, *Remembering and Forgetting*, London, p. 229.

persons seem generally clever with their muscles. While there seems ample evidence for the existence of general intelligence, the results of simple tests for isolated motor performances from which intelligence has been excluded, as far as possible, give extremely low or negative correlations with each other. Moreover, these results do not warrant belief in any special connexion of simple motor abilities with intelligence.[24]

From these results far-reaching deductions have been made by some writers. One is that there is no general capacity, no 'motor type' of person. The conclusion concerning vocational tests has been drawn that tests for ability in any performance give valid results only when the test-performance is identical with that for which the test is being administered. They support the 'sample' as against the 'analogous' test.[25]

Yet an alternative explanation of Perrin's and Muscio's findings is possible, based upon a suggestion made by Sir Henry Head to the present writer. Their tests involve the simplest muscular co-ordinations. Many of them were confined to limited parts of the body. From the tests used by Muscio, demands upon intelligence were excluded.

As a consequence, the bodily mechanisms involved may have been controlled by relatively low levels of the nervous system. The significance of the test-results, therefore, would not exclude the possibility that in *skilled* performances a higher, more complex power might employ and co-ordinate the simple mechanisms.

Another consideration is important. In intelligence tests, that the subjects will do their best is (perhaps not quite justifiably) taken for granted. Yet it cannot be assumed that the motives urging university graduates and undergraduates (the performers in these motor tests) to excel in a simple, trivial and often boring motor test are identical with those producing keenness in a recognised test of intelligence. For to do very badly in several tests generally agreed to measure intelligence would cause more shame in university people than proved inability to thread needles or to loop wool quickly over pegs.

The above tests, therefore, being concerned with simple motor abilities, are important for the study of skill, rather as suggesting lines of inquiry than as affording data.

Transfer of training between motor abilities.

Another method of attacking this problem is to re-set it in the well-known form of the transfer of training.[26] Subjects are intensively trained in some skilled activity until their curves of practice have shown a marked rise over a fairly long period. One discovers then if the undoubted ability gained in the test-activity has been transferred to apparently related or similar performances. Many 'controls' are needed in such an experiment.

[24] F. A. C. Perrin, *Jour. of Exp. Psych.*, 1921, 4, pp. 24–56; B. Muscio, *British Jour. of Psych.*, 1922, 13, pp. 157–84; see also Perrin and Klein, *Psychology*, London, 1927, pp. 356 *ff*.

[25] This conclusion concerning simple motor dexterity has recently been supported by the results of experiments. *Cf.* J. N. Langdon, Edna M. Yates and T. H. Pear, 'The Nature of Manual Dexterity and its Relation to Vocational Testing,' *Nature* May 12, 1928, pp. 773–4.

[26] This technique has not been extensively used in the investigation of skill.

Recently Dr. C. E. Beeby[27] investigated the transfer of ability between performances involving one or both hands. Subjects were trained, blindfold, to trace with a metal stylus (connected, to record errors, with an electric circuit) along strips of metal, shaped in simple geometrical forms. An initial positive transfer was found. With further practice it gradually diminished. Finally, it passed over into its antithesis, interference, or negative transfer. The amount of transfer, both initial and final, proved to be the same whether it occurred

(*a*) from one hand's performance to that of the other,

(*b*) from a double-handed action to one of the single-handed movements constituting it,

(*c*) from a single-handed to a double-handed action.

Beeby concluded that the agency of positive transfer was a *general mental attitude*. He found no positive transfer of specific manipulative habits. Indeed, nothing but interference occurred between them. This interference explains the final negative transfer.

An extensive investigation into transfer of training in a low-grade skill was recently carried out in the Manchester laboratory by J. N. Langdon and Edna M. Yates.[28] Possibly for the first time in such experiments a number of conditions were rigidly observed. These were the domination of the learners' motives, the selection of a really skilled performance, though a simple one, as the test-activity, the testing of similar control subjects in strictly comparable conditions, and the simultaneous provision of ' analytic ' tests, *i.e.* tests of simple powers which appeared to be components of the training-activity.

The operation selected for intensive training was modified from one in the driving-chain industry. The subject sits before a small turntable. It carries fixed pairs of spindles upon which links have been placed. As he brings each of these in turn before him, he removes it from the turntable, dropping the link into a box at his right hand. Simultaneously he takes another link from a box at his left and places it upon the pair of spindles, reinstating the whole upon the turntable. He then rotates the turntable, bringing the next unit into position, and repeats the whole operation.

Thirty-two unemployed boys aged sixteen, paid at a high piece-rate, were thus trained, each for two weeks. These constituted the ' trained group.' Before training, each boy's performance was measured in the various tests designed to detect the presence of transfer, if any.

These had been selected after a careful observational analysis of the operation with the links and spindles. Most of them were simple tests of manual dexterity, such as inserting matches in holes, filling a box with matches, slipping curtain-rings over a rod, threading links with twine, reproducing from memory the angle of an arm-movement, or the force with which a recording anvil had been struck by the subject's hammer,

[27] Unpublished research in the psychological laboratories of University College, London, and Manchester University.

[28] ' An Experimental Investigation into Transfer of Training in Skilled Performances,' *British Journal of Psychology*, 18, 1928, pp. 422–37. This research was made possible by financial help from the Industrial Fatigue Research Board and the Lewis Scholarship in Applied Psychology.

static and dynamic steadiness, and—to discover if the training in the skilled action had affected more purely 'mental' functions—tests in mental arithmetic and tests involving the rapid and accurate cancellation of specified letters in a page of print.

This series of tests was given on three occasions: (1) before training, (2) at the end of the first week, (3) at the end of the fortnight. They may be called transfer tests, 1, 2, and 3.

Identical tests were given, in the same order and at the expiration of the same three periods, to twenty-eight similar subjects who meanwhile received no training. These were the control group.

Since the trained group contained thirty-two and the control group twenty-eight subjects, statistical treatment is justifiable. In no instance was the difference between the trained and the control group, with regard to their improvement in transfer test 3 as compared with 1, of such a magnitude as to exclude the possibility of its being due to chance factors. In some results the brief practice afforded by the test itself was definitely shown to have had more effect than the intensive training in an apparently analogous performance.

The experiment supports the view that in such conditions training in a low-grade skill is specific rather than general. These manual habits did not transfer.

How may such a clear-cut result be explained? The following considerations may be suggested:

Writers upon transfer of training[29] who know the experimental evidence believe that one of the chief agents of transfer is the formation of a sentiment. In the present experiment there was no encouragement to form a general sentiment about the acquisition of skill, which might spread to other skills.

The conditions were as unsentimental as might be. The workers were never exhorted to do their best. The only encouragement was the very real one of immediate personal gain. Conversely, slack work automatically caused less pay. This was made known to the learner with little delay. The personal influence of the experimenters was as little and as unchanged as possible. The workers were paid, and highly paid. to transfer. Yet demonstrable transfer did not occur.

It may be urged that when practice in a skill has hardened it into a 'habit-unit' this latter becomes partially dissociated from the rest of the personality. Examples might be given of the way in which low-grade industrial skills require minimal attention. Transfer, therefore, might not be expected between this almost 'insulated' entity and the rest of the personality. Hardening the skill into a series of habits may have decreased the possibility of 'ordinary' transfer.

Since the test was given three times; the subjects were not 'saturated'

[29] Ballard, P. B. *The Changing School*, London, 1925. Fox, C., *Educational Psychology*, Cambridge, 1927. Pear, T. H., *Skill in Work and Play*, Chapter V. Perrin, F. A. C., and Klein, L. W., *Psychology*, London, 1927, pp. 280–286. Sandiford, P., *Educational Psychology*, London, 1928, pp. 275–300. Thomson, G. H., *Instinct, Intelligence and Character*, London, 1925. Thorndike, E. L., 'Mental Discipline in High School Studies,' *Jour. of Educational Psychology*, XV., January and February 1924, pp. 1–22, 83–98.

with practice at the second test; and even at the third, practice was not at a maximum, data may be obtained concerning this point by comparing the results of the three tests.

A comment made by Mr. F. C. Bartlett is that, at school or college, practice in different activities between which transfer is supposed to occur is not acquired in the manner of this experiment. Pupils do not practise one task exclusively for days and then turn equally exclusively to another. During any one day several different activities (at least six, but at school often many more) are practised successively. This might facilitate the transference of attitudes towards the work, ideals, sentiments and knowledge of methods applicable to different tasks.

To examine these hypotheses the experiment described above is being continued in a modified form.

This conception of the isolation of a habit has obvious relationships, which cannot be explored here, to that of the conditioned response.

The evidence seems now to establish that the problem of transfer may be divided into two parts:

(*a*) Transfer resulting from and due merely to exercise of any particular function;

(*b*) transfer resulting from extension of attitudes, sentiments, ideals or knowledge of methods, where the particular function trained was the vehicle of these mental powers.

It now seems certain that (*a*) is rare, and that (*b*) definitely can occur. But in educational institutions, where subjects or parts of subjects are taught by different persons, the chances of transfer through common applicable methods discovered by the learner himself, or through sentiments, is much less. And the automatic occurrence of transfer can never in the future be *assumed* by anyone conversant with the facts.

SECTION K.—BOTANY.

SEX AND NUTRITION IN THE FUNGI.

ADDRESS BY

PROF. DAME HELEN GWYNNE-VAUGHAN, D.B.E., D.Sc., LL.D.,

PRESIDENT OF THE SECTION.

I THINK all members of Section K know the unhappy reason which prevents us to-day from hearing an address from the President of our choice, and I am sure that I may convey to Prof. R. H. Yapp our sincere sympathy and regret and our cordial hopes for his speedy recovery. I came into the picture because I had been appointed a vice-president, and that, I am proud to remember, was largely due to the association of my husband's name with the University of Glasgow.

At the last Glasgow meeting in 1901 the President of the section was Prof. Bayley Balfour, whose memorial we shall see unveiled on Saturday. He referred to the excellent quarters in which we find ourselves as 'this magnificent Botanical Institute' opened 'a few months ago . . . with all the distinction that the presence of our veteran botanist, Sir Joseph Hooker . . . could give to the ceremony.' Much has changed in the intervening twenty-seven years, but not the hospitality of the Department of Botany in Glasgow. Some of the changes in botanical outlook are vividly brought home to a reader of the presidential address on angiosperms in 1901, a period when triple fusion was new and pteridosperms were unknown.

My first duty is to refer to the botanical losses of the year. Benjamin Daydon Jackson died, as the result of an accident, after sixty years of unremitting work on botany; William Charles Frank Newton was near the beginning of his scientific career, but had already done enough to make his loss a heavy one. Edward Francis Linton and Robert Miller Christy will be remembered for their work on British plants, and Sir Harry Johnston for his collections and discoveries overseas.

Apart from two brilliant addresses on plant pathology by Marshall Ward in 1897 and V. H. Blackman in 1924, the fungi have never been the subject of a presidential address in Section K. Last year the President dealt with the elementary types of holophytic plant life, and traced their origin from the pigmented Flagellata; it is not inappropriate that we should turn to-day to saprophytic and parasitic forms.

These have often been assumed to be derived in small groups from diverse phyla of green plants, but increasing knowledge of the fungi has emphasised the characters that they have in common, and has shown many of their resemblances to the higher algæ to be superficial, examples of homoplasy rather than homology. There are exceptions to this as to

every generalisation. No one would doubt that such saprophytes as the Polyblepharidaceæ are truly algal, and *Monoblepharis*, though classified as a fungus, is possibly allied to the filamentous green plants.

It may be hazarded that the fungi as a whole have their origin, perhaps a common origin, among the Protista, and that they form a line of evolution parallel with those of animals and green plants, in some sense comparable to both, but derived from neither.

Phycomycetes.

The simplest members of the Phycomycetes show biciliate zoospores, the cilia being lateral and oppositely directed; in *Olpidium*[1] and *Synchytrium*[2] sexual reproduction is achieved by the union in pairs of zoospores which have been retarded in development by dry conditions, while in *Monochytrium Stevensianum*[3] the fusion of naked, uninucleate amœbæ has been described.

Very early in the development of the fungi, however, appears a more specialised process, and one which has established itself as characteristic of the group. In *Olpidiopsis*[4] the individual consists of a single, multinucleate protoplast surrounded by a delicate wall; two such cœnocytes of different size, if side by side in the same host cell, may fuse, the contents of the smaller passing into the larger. Similar union is accomplished in *Zygorhizidium*[5] by means of a conjugation tube put out by the smaller individual. In *Polyphagus*[6] the individuals are uninucleate; here again the conjugation tube is formed by the smaller cell, but the contents of this cell do not pass beyond the end of the tube, and are joined there by those of the larger, so that the wall of the zygote is provided by the smaller participant, which also develops the tube.

I have called attention to this case because it emphasises the danger of generalisation in respect of the sexual apparatus of the fungi. Apart from the retarded zoospores of *Olpidium* and *Synchytrium*, the sperms of *Monoblepharis*, and perhaps the oospheres of the Saprolegniaceæ and their allies, gametes are unknown, and we have to consider the association of walled gametangia. This renders useless our usual criteria of sexual differentiation. The male gamete is defined as the smaller and more active, the female as larger and stored with food, but there is nothing in our experience of green plants to justify the assumption that the antheridium need differ from the female organ either in size or activity. Two criteria remain, the superior activity, not of the antheridium, but of its contents, corresponding to the activity of the male cells in other plants and animals, and the production of the zygote wall, characteristically a function of the female cell or its environment. Bearing these characters in mind, no difficulty arises among higher forms in distinguishing the male and female gametangia. *Polyphagus* may be regarded as still in the experimental stage in this respect.

Among Oomycetes the contents of the oogonium may form a single, multinucleate mass, into which enter numerous antheridial nuclei, or one female nucleus only may be selected while the others disintegrate, or several uninucleate masses may be formed, as in *Saprolegnia*, and each be separately fertilised. In every case the conjugation tube is antheridial

Already among these fungi the development of the contents of the oogonium without fertilisation has become common, and information is beginning to accumulate as to the physiological conditions which determine the appearance of male or female organs or of both. Thus Klebs was able to maintain *Saprolegnia ferox*[7] in a vegetative condition so long as fresh, unaltered nutriment was provided, but sporangia appeared on transfer of the mycelium to pure water, and gametangia in the presence of staling products, especially when the food supply was sufficiently concentrated to prevent sporangial development. In nutrient solutions poor in phosphates parthenogenetic oogonia were obtained, while both *Saprolegnia ferox* and *Achlya polyandra*[8] give rise, on protein substrata, to abundant antheridia and oogonia in the presence of calcium phosphate, and to a smaller number when provided with phosphates of sodium or potassium. In *Phytophthora erythroseptica* an increase in the proportion of available carbohydrate has been found by Dr. Barnes to limit the formation of gametangia, and it is well known that, in nature, the vegetative development and sporangial activity of a number of species takes place on the living host, whereas the sexual organs appear when the host is dead and the fungus is growing as a saprophyte ; doubtless, under these conditions, staling products tend to accumulate.

In the great majority the mycelia are capable of bearing both male and female organs, but *Phytophthora Faberi*[9] and species of *Dictyuchus*[10] have been shown to be dioecious.

In the Mucorales sexual reproduction has long been known to take place by the union of large, multinucleate gametangia. These may be similar in form or recognisably male and female, they develop in contact, the wall between them is dissolved, and their contents mingle without the intervention of a conjugating tube. In many species the gametangia can be obtained with ease, and their appearance is clearly associated with a suitable provision of food and water. Thus in *Sporodinia grandis*[11] the fertile hyphæ are rich in glycogen and their formation is conditioned by the presence of carbohydrates as well as by a saturated atmosphere. In other members of the alliance, gametangia proved most uncertain in their development, and it was not till 1904 that Blakeslee[12] was able to show that they appeared only along the line of junction of two separate mycelia. There was here a new conception of sexual differentiation ; since the gametangia were similar both in size and behaviour, it was impossible to describe one as male and the other as female ; yet they, and the mycelia which bore them, clearly differed in an essential character, and Blakeslee applied to them the arbitrary designations of (+) and (—). In some cases a difference of vegetative luxuriance distinguished the two strains, in others a (+) or a (—) strain could only be defined by its capacity to produce zygospores with the other. It seemed evident that there existed, in effect, both in the sexual organs and in the thalli which bore them, a physiological differentiation of sex unaccompanied by morphological distinction. To species possessing (+) and (—) strains Blakeslee applied the term *heterothallic*, using *homothallic* for those in which zygospores could be obtained in single spore culture.

In *Mucor Mucedo*[12] the power of conjugation may be inhibited by unfavourable conditions, but so far nutritive or other factors have not

been found which will produce sex intergrades[13] or transform (—) into (+) or (+) into (—) mycelia.

It is, I think, to be regretted that the term *heterothallic* has recently been used to indicate the condition of dioecism in the gametophyte. The old sex terms are adequate for this purpose and there is a need, which *heterothallism* admirably fulfils, for a term appropriate to a thallus having two or more physiologically distinct but morphologically similar strains, whether the difference between them be sexual or no. I propose to employ the word in that sense this morning.

It is a curious point in the Mucorales that, while heterogametangia are common, these are never found in correlation with the heterothallic condition. In heterothallic forms the two gametangia of a pair may differ in size, but both large and small gametangia are borne on the same mycelium. There is, perhaps, a faint suggestion here that some factor other than sex may be at work in determining the heterothallic condition.

Basidiomycetes.

When we turn to the higher fungi, which are characterised by the possession of a septate mycelium, we find one of their most striking vegetative characters to be a tendency to fusion between the hyphæ. A branch will grow out, wander a little way, turn and fuse with the parent filament again; it will even do this two or three times at short intervals. A hypha will undergo dichotomy, and a cross connection will unite the diverging branches. Stranger still, germ tubes from several distinct conidia will flow into one another, and the composite mycelium thus produced will continue its ordinary development. Presumably the stimulus responsible for such unions is nutritive, but there is at present no evidence that they are conditioned by general starvation. Certainly they complicate the question of what may be regarded as an individual in the fungi, since, where mycelial fusions have taken place, nuclei from several sources may be intermingled in the same cell. In the smuts, mycelia from three or four species have even been described[14] as involved in the same group of fusions, and in Ascomycetes two species may apparently take part[15].

It is perhaps unfortunate that the suggestion that some of these mycelial fusions are sexual was first made in the Hymenomycetes, where sexual organs, the ordinary criteria of sex, are wholly lacking. Kniep[16] from 1915 onwards, and Bensaude[17] independently in 1918, described the union of two mycelia as a necessary preliminary to the formation of the sporophore in certain species, and characterised such a mycelial fusion as a sexual act.

On the germination of the basidiospore in, for example, *Coprinus fimetarius*, a multinucleate filament is put out and grows for a time, dividing into uninucleate cells. This is the primary mycelium. All primary mycelia are similar in appearance, but they are of two kinds, which, here also, are distinguished as (+) and (—). Should a (+) and a (—) mycelium meet, fusions occur, with the formation of secondary mycelium on which sporophores may develop, and which is characterised by the presence of clamp-connections. In *Coprinus fimetarius* oidia are liberated from the

primary mycelium, and their germination among hyphæ of opposite strain may initiate the secondary condition.

Even in that incalculable group, the fungi, there are few things more curious than the formation of clamp-connections and the method of nuclear division which has been described as associated with them. The cells of the secondary mycelium are binucleate, one nucleus being presumably derived from each of the primary mycelia. Simultaneous division of two or more nuclei present in the same cell is almost universal in plants, and such a division, with spindles parallel to the long axis of the filament—the natural position in the narrow cells of a hypha—would readily separate two freshly formed nuclei from their sisters. Instead of this, the cell grows out laterally, forming a branch which at once bends round and fuses with the cell of origin. One of the daughter nuclei, still attached to its spindle, wanders through this branch, or clamp-connection, and so rejoins the daughter nucleus of the other member of the pair. Both in the main cell and in the clamp, walls appear and the division is complete. It would be of interest to know either the origin, or the use—if any—of this elaborate procedure ; it is not a subject on which I feel able to hazard a guess. Whatever their relation to the nuclei, clamp-connections, when present, form a convenient means of recognising the secondary mycelium and the associated binucleate condition. It may be noted that their occurrence is not universal, *Coprinus ephemerus* and *C. curtis*, for example, developing without them in mass culture[18].

In many of the Hymenomycetes the binucleate condition does not arise till the formation of the sporophore is well advanced. In mushrooms the cap and stem are composed of multinucleate cells, binucleate cells appearing first in the gills[19]. In *Boletus granulatus* the cells of the stalk are multinucleate, whereas those of the ring and of all parts of the cap contain two nuclei[20]. In other forms, as in *Coprinus*, the sporophore is made up wholly of binucleate cells. There is evidence that in nature, in such cases, the sporophore is derived from two spores in heterothallic species, and, in homothallic species, from a single spore[21]. Where part of the sporophore consists of multinucleate cells, the species is presumably homothallic, though the possibility is not excluded that several similar mycelia may share in the construction of one fructification, or that fusions may occur between them.

Since Kniep's and Bensaude's discovery a very full study has been made of heterothallic members of the Basidiomycetes. In some cases the primary mycelium, if it does not encounter an appropriate strain, appears to remain permanently sterile ; in others it sooner or later produces clamp-connections and sporophores. This was observed, for example, in *Coprinus Rostrupianus*,[22] where fifty-six per cent. of the single-spore mycelia became spontaneously diploid in the course of six months. Similarly Vandendries found that in the wild-fruit bodies of *Paneolus campanulatus* and *P. separatus*,[23] some of the spores were definitely (+) or (—), but a considerable number gave positive reactions with strains of both kinds. Nor is the number of strains limited to two ; in *Aleurodiscus polygonus*,[24] *Coprinus lagopus*[25] and other species, four strains are found, only the appropriate pairing being fertile. The character of the strains

appears to depend in these cases on two sets of allelomorphic factors, A, a and B, b. Each spore, and hence each primary mycelium, carries a member of either pair, so that they may be AB, Ab, aB or ab. Secondary mycelium develops only when the combination AaBb has been achieved. In *Coprinus lagopus*[22] half the basidia carry the four spores AB, Ab, aB and ab, while twenty-five per cent. develop two AB and two ab spores, and the remainder two Ab and two aB. This is what might be expected if the characters A, a, B and b are transmitted on mendelian lines, and if the allelomorphs A, a and B, b are independently inherited. One cannot but admire the delicate and persevering work involved in separately collecting and germinating the spores from so minute an object as a basidium, thanks to which the mode of transmission of these characters seems to have been fully established.

Their significance, however, is by no means so clear. It is customary among the workers in this field, following the analogy of the Mucorales, to refer to the distinction between (+) and (—), or between AB, Ab, aB and ab strains as a sexual difference ; but, if we accept this point of view, we must greatly extend our notions of sex. Not only must we accept the occurrence of four sexes, but we must assume that sex is variable, male or female strains spontaneously becoming hermaphrodite. And even that is not sufficient. In a number of species mycelia from all the spores of distinct 'sexes' on one sporophore may be perfectly fertile with those from all the spores on another sporophore[26]. In other words, mycelia of one sex achieve fertile unions not only with mycelia of the opposite sex, but with mycelia of the *same* sex, provided that these are derived from a different source. And yet 'sex' in these fungi is only recognisable as a capacity for selective fusion. In plants possessing recognisable sexual organs, it might be possible to unravel such a tangle, and we may turn, therefore, with special interest, to groups less remote than the Hymenomycetes from normal sexuality.

In the smuts it has long been known that the basidiospores or their products fuse readily in pairs ; Dangeard,[27] in 1894, first described the union of two nuclei in the young brand spore ; later it was realised that nuclei first became associated in the paired basidiospores and that the intervening mycelium consisted of binucleate cells. In *Ustilago antherarum* and other species,[28] as in the Hymenomycetes, two or more strains may exist, and fusions are not indiscriminate but between cells of opposite strain. The formation of strains between which fusion does not occur may be induced by cultivation on media rich in albuminous compounds, and, conversely, the tendency to fuse may be enhanced by an ample supply of oxygen or by scarcity of food.

In the rusts, thanks to the work of Blackman[29] in 1904, Christman[30] in 1905 and subsequent investigators, we have a pretty full knowledge of the morphology of the reproductive apparatus. In the *eu* forms, which possess a complete life cycle, both uredospores—the accessory spores of the sporophyte—and teleutospores are produced on a mycelium of binucleate cells. Nuclear fusion takes place in the teleutospore cell, which is the young basidium, meiosis follows, and four uninucleate basidiospores are shed. The basidiospore, on germination, gives rise to a mycelium, the cells of which contain each a single nucleus, and some of them, forming

a regular layer, serve as the basal cells, or oogonia, of the æcidium. The binucleate condition now supervenes; in some species a vegetative nucleus migrates into each basal cell, in others the basal cells unite in pairs, and jointly cut off a binucleate structure which will form æcidiospores.

The æcidium may be regarded as a sorus, or group, of spore-producing cells, comparable to the sorus which gives rise to the uredo- or teleutospores; it is, however, the product of the gametophyte and the scene of transition from the haplo- to the diplophase.

On the same mycelium of uninucleate cells which bears the young æcidia appears a fourth type of sorus, the spermogonium or pycnidium, consisting of a layer of narrow filaments from the tip of each of which a series of small oval cells is budded off. These cells, the spermatia or pycnospores, each possess a large, dense nucleus, scanty cytoplasm and apparently no reserve material; they have never been seen to form a mycelium, though they can be induced to undergo a form of yeast-like budding in solution of honey or sugar, and Professor Robinson informs me that he has observed the same thing under natural conditions. As long ago as 1882 Rathay[31] called attention to the attractive characters of the spermogonia, their scent in many cases, their sugary secretion, and the bright colours imparted to the neighbouring host tissue; he suggested that insects were responsible for the distribution of the spermatia. The function of the spermatia, however, has long been a puzzle; as conidia they were oddly constructed, as antheridia there seemed little opportunity for them to reach the basal cells of the æcidium; in either case they appeared to be vestigial.

A new aspect has recently been given to this problem by two letters to 'Nature,'[32] describing the experiments of J. H. Craigie on *Puccinia Helianthi* and *Puccinia Graminis.* In the former species he found that, when basidiospores are shed on the leaf of the sunflower, spermogonia appear in about eight days. Ten or eleven days after sowing, when mycelia from different infections overlap, æcidia are found in fifty per cent. of the cases. The remaining infections, whether simple or compound, do not produce æcidia for three weeks; later nearly half of them do so. This seems a straightforward case of heterothallism; the production of spore fruits is induced or stimulated by the association of two mycelia of presumably different strain, but, as in the Hymenomycetes, fructifications may more slowly develop without such encouragement. In his second letter Craigie adds a most interesting point; observing the visits of flies to his spermogonia, he was reminded of the old suggestion of their function as distributors, and was induced to mix the spermatia from several spermogonia and apply the material to his infections. In nearly every case æcidia were the result. The inference is drawn that the foreign spermatia served as a stimulus to development. Craigie regards the two heterothallic strains as of different sex, and the spermatia as conidia. It is possible that they play the same part as the oidia of *Coprinus fimetarius*, but unfortunately microscopic details are not available. It will be most interesting to know how the spermatium, after landing on the epidermis of the leaf, penetrates to the endophytic mycelium of the rust. Such knowledge should decide its antheridial or conidial function.

Ascomycetes.

In the Ascomycetes the sexual apparatus has in many cases been shown to be functional, with well differentiated male and female organs. In the simpler species, among the Plectascales, the gametangia are similar twisted filaments; in *Eremascus albus* these fuse,[33] the contents of both passing into an enlargement which becomes the ascus directly and gives rise internally to eight spores. In *Endomyces Magnusii*[34] the gametangia differ in size, the contents of the smaller passing into the larger which becomes the ascus. In *Endomyces Lindneri*[35] the product of fusion is not an ascus, but buds out one or two short hyphæ at the end of each of which an ascus is developed. Here we have the beginning of the vegetative sporophyte which, in the higher Ascomycetes, forms a considerable mass of ascogenous filaments bearing numerous eight-spored asci. In the first two divisions of the nucleus of the ascus meiosis occurs, and the ascospores give rise, on germination, to the vegetative gametophyte. I do not propose to discuss the complicated cytology of this stage, but to accept, for my present purpose, the common ground that, in some cases at any rate, male nuclei enter the oogonium and sooner or later fuse with the female nuclei; while, in other species, or in the same species under different conditions, more or less marked apogamy prevails, so that the antheridium may be functionless or missing, the oogonium still giving rise to ascogenous hyphæ, or the female apparatus also may have disappeared, the sporophyte being vegetative in origin.

Proceeding from the simple, intertwined gametangia, we may recognise a number of forms in which the female apparatus, or archicarp, is differentiated into three parts, a stalk, commonly multicellular, an oogonium, which may or may not become septate after the fertilisation stage, and a trichogyne or conjugation tube, which also, strangely enough, is often septate, the septa, at any rate in some cases,[36] having been shown to undergo perforation. Evolution seems to have been along two lines: in one, characteristic of the Pyrenomycetes, the archicarp remains narrow and elongated, and septation is increased; in the other, common among Discomycetes, the oogonium is globose and septa are not developed. This type is admirably exemplified by that classical subject of investigation, *Pyronema confluens.*

Corresponding to the discomycetous type of archicarp, we find a rather large, stalked, oblong antheridium; while, in the higher Pyrenomycetes, the antheridium is reduced in size, and at last appears as a small, uninucleate cell, detached from the end of an antheridial hypha. Such antheridia have never been proved to function, and have by many been described as conidia. Craigie's work on the spermatia of rusts indicates the need of a reinvestigation of such forms.

In both Pyrenomycetes and Discomycetes dioecious species have been reported. Thaxter,[37] in 1896, described the development side by side of male and female plants of the laboulbeniaceous fungus, *Amorphomyces Falagriæ*; in this species the ascus contains spores of two sizes, and these male and female producing spores are shed in pairs. It is one of the puzzling aspects, not merely of the fungi, but of plant economy as a whole, that elaborate morphological provision for exogamy seems so often to be neutralised by the common origin of the sexual elements or of the plants

which bear them. The cases of highly specialised entomophily where the insect passes from flower to flower on the same inflorescence, and the formation of dwarf males from the egg-bearing plant of *Oedogonium* are examples of the same problem.

Among the Discomycetes Dodge[38] in 1920 reported in *Ascobolus magnificus* the development of antheridia and oogonia along the line of junction of two mycelia. Though the oogonium is globose, the trichogyne here is long and septate, and coils round the antheridium; but details of fertilisation are not available, nor has it been finally ascertained that the sexual organs originate only on hyphæ of different strains. If the latter should prove to be the case, simple dioecism is indicated, and this is borne out by the fact that, as in the Mucorales, the sexual organs do not appear till opposing mycelia have made contact. The same criterion applies in the case of *Ascobolus carbonarius*,[39] where the trichogyne is even longer and more richly septate, and the antheridium is described as conidial; apart from the fact that ascocarps arise where two strains meet, nothing is known of the dioecism or heterothallism of this form. *Ascobolus furfuraceus* and several other species produce fruits in single spore culture.

As early as 1914 Egerton[40] described in *Glomerella cingulata*, one of the Sphaeriales, a phenomenon which may possibly fall into line with more recent observations. In this fungus there are two strains which differ in appearance; that designated as (+) grows rapidly, develops white or light grey aerial hyphæ and produces a few perithecia which reach normal maturity. On the (—) strain aerial filaments are scanty, while perithecia are numerous, but asci do not ripen in culture except on acidified oat agar, and even then are irregular in form. Where the two strains meet fertile perithecia are abundant. Moreover, the asci in perithecia on a (+) or a (—) mycelium produce only corresponding spores, whereas those in perithecia along the line of junction have been shown to contain spores of both kinds. Here it seems evident, not only that some stimulus is conveyed by the association of two mycelia, but, since the (+) and (—) characters are inherited through the ascus, that a mingling and ultimately a fusion of (+) and (—) nuclei can take place. The species is remarkable for the morphological difference of its (+) and (—) strains.

A more orthodox case of heterothallism—using the term in its simplest sense to indicate the presence of two or more kinds of mycelia—was described by Derx[41] in 1926 for *Penicillium luteum*. In this fungus twelve mycelia were grown from single ascospores; perithecia were developed only where two appropriate mycelia met, and these mycelia were further differentiated by their feebleness or vigour. An energetic mycelium, growing alone, gave rise to ascocarps, though without asci, liquefied gelatine, and stained the substratum bright orange; a feeble mycelium showed none of these activities. When two vigorous mycelia, one (+) and one (—), were brought into contact, large numbers of perithecia appeared; when two feeble mycelia met the perithecia were but few, while one vigorous and one feeble strain gave an intermediate supply. Evidently, apart from the (+) and (—) character, some nutritive factor is here at work.

In *Giberella*[42] also, the ascigerous stage of *Fusarium moniliforme*, and in *Ophiobolus cariceti*,[43] a cause of *take all* or *whitehead* disease on wheat,

fertile perithecia have been reported along the line of junction of two strains, but full details are not available.

In 1926 Shear and Dodge[44] described a new genus, *Neurospora*, the red bread mould, which they classified among the Hypocreales in the neighbourhood of *Melanospora*. *N. tetrasperma* has four binucleate spores in the ascus; in *N. sitophila* each of the eight ascospores contains one nucleus. Grown in culture *N. tetrasperma* readily produced ascocarps, while, in *N. sitophila*, perithecia appeared only at the junction of (+) and (—) mycelia. Further, mycelia from the occasional uninucleate spores of *Neurospora tetrasperma* were heterothallic like those from the spores of the eight-spored species. Dodge[45] and his colleague Wilcox,[46] who studied *N. sitophila*, concluded that the character distinguishing the (+) and (—) strains was carried by the nuclei and found evidence that its distribution took place in the second division in the ascus. Dodge[47] succeeded in intermingling the mycelium of *N. sitophila* with that of the heterothallic form of *N. tetrasperma*, and in obtaining material with some of the characters of each. Unfortunately no information is available as to the sexual apparatus of these fungi, or of the part it plays, if any, in the relation of (+) and (—) strains.

This relation is described by Dodge, and by most other workers on heterothallism in the Ascomycetes, as in the Basidiomycetes, in terms of sexual difference. I have tried to state their facts without theoretical implication.

Lately some work has been in progress in my laboratory at Birkbeck College on the coprophilous species, *Humaria granulata*, in which Prof. Blackman and I,[48] some twenty-two years ago, described the archicarp, terminating in a globose oogonium, and giving rise to ascogenous hyphæ without the intervention of an antheridium. I am not sure, in adducing the case of *Humaria*, whether I am bringing forward that additional term which sometimes solves an equation, or only making an insoluble equation more complex.

We found that the mycelia of *Humaria*, in single spore culture, were of two kinds, and that ascocarps developed only along the line of junction of (+) and (—) infections. So far the case was an ordinary one of heterothallism, but microscopic examination showed that both (+) and (—) mycelia bear well-grown female organs, though these produce ascogenous hyphæ only where (+) and (—) strains have met. The contact of the mycelia is followed by fusions between their branches, and it is in the neighbourhood of such points of union that successful archicarps are found. Transverse walls do not at first appear in the archicarp, so that little difficulty is presented to the passage of nuclei from both mycelia to the oogonium.

It is impossible to regard as differing in sex these two mycelia which both bear normal, though apogamous, female organs; and it is therefore inevitable, in *Humaria* at any rate, to seek some explanation of heterothallism which does not invoke sexual difference. The most promising alternative appears to be a difference in nutrition. If we can induce *Humaria* to fruit on synthetic agars, we hope to make a direct test of this hypothesis. Meantime there is other work from which indirect information can be obtained.

The Nutritive Requirements of the Fungi.

The life-history of a fungus may as a rule be divided into three stages: a period of vegetative growth, a conidial phase, and a phase characterised by the development of the sexual apparatus. The change from the vegetative condition may be influenced by food, light, temperature, humidity, aeration or the encounter of mechanical obstacles; thus *Sporodinia* tends to form gametangia when the air is saturated with moisture, while *Polyporus*,[49] *Lentinus*[50] and *Pyronema* will initiate their fructifications only in the presence of light. Anyone who has grown Ascomycetes in culture is accustomed to the appearance of ascocarps near the edge of the dish, where free growth of the mycelium is checked, and many of these fungi are also encouraged to fruit by a moderate increase of temperature. It is possible that both reactions may be referred to nutritive causes, since high temperature, by increasing growth, uses up the available food, and a mechanical obstacle means that areas of unstaled substratum can no longer be invaded. Possibly, also, a nutritive cause may be assigned to the production of ascocarps of *Ascobolus*[51] and *Aspergillus*[52] in the presence of bacteria, and to the more curious case of *Lachnea abundans*, communicated to me by Dr. Barnes. This species fruits readily when grown on synthetic media with scraps of filter paper, but not if the paper is replaced by 0·3 per cent. glucose; in contact with *Penicillium glaucum*, however, it fruits on the latter medium.

Most fungi are very sensitive to the presence of appropriate carbohydrates. On substrata rich in carbohydrate *Phytophthora erythroseptica* fails to form gametangia, but *Sporodinia grandis* will not produce them in its absence. Similarly *Eurotium herbariorum* fruits best on media containing a large percentage of cane sugar, while other fungi, like *Pyronema confluens*,[53] *P. domesticum* and *Lachnea abundans* show increased vegetative development under similar conditions, but remain persistently sterile. Some of the coprophilous sordarias fruit in culture only in contact with scraps of filter paper or grass; others are indifferent to such substances.

The nitrogen relation is more general. The Saprolegniales tend to form sexual organs in standing water, when the aquatic population is high and the nitrogen content of the pool increased. Ascomycetes need some source of nitrogen before gametangia can be formed; there is evidence,[53] however, that these cannot develop till the substratum is almost depleted of nitrogen compounds. The observation that heavy nitrogenous manuring prevents the appearance of mushrooms and their allies is in harmony with this. Nitrogen compounds are essential, but must not be present in excess.

Information with regard to other food materials is scanty, but phosphates, potassium, magnesium and calcium salts, and, in some cases, a trace of iron have been found to be advantageous. The formation of staling substances is often important, probably as a means of checking vegetative growth; high concentrations of sugar may have the same effect, an osmotic factor being presumably involved. The evidence points to specific requirements in a number of forms, and, in all, to the need of appropriate food before fructifications can be produced.

Saltation.

In this, as in other characters, the fungi are capable of marked variation. Often the varieties grade into one another; in some cases they are dependent on the content of the substratum and revert to the original form when the original food material is supplied; in some they return gradually, even under unchanged conditions, to the character of their precursors. Stable variants, however, are common, and their sudden origin in species under observation has often been recorded. Barnes,[54] in *Eurotium herbariorum*, found that they could be induced by the application of heat to the spores, and Brown,[55] in *Fusarium*, reported their survival on media which combined high concentration with minimal staling capacity, so that, growth being long continued, the altered hyphæ had a chance to develop.

It is possible that some of these variants may arise in nature as a result of conditions which the fungus barely survives, and that some may be due to mutations comparable to those of animals and green plants. But account must be taken in the higher fungi of the multinucleate character of the vegetative cells, and of the occurrence of mycelial fusions which bring together unrelated nuclei. We are profoundly ignorant of the effect on development of a nucleus surrounded by unfamiliar cytoplasm, or of two or more nuclei in an environment to which only some of them belong. These problems will demand intensive study before the phenomenon of saltation begins to be understood, but it is already established that saltation affects both physiological and morphological characters, that many saltants are stable, and that their peculiarities are inherited.

Food and Heterothallism.

How, then, is a nutritive explanation applicable to the heterothallism of *Humaria*? We know that the production of fructifications is dependent on appropriate food, and that new strains, differing in their food relation, readily arise. Suppose that the (+) mycelium be a saltant possessing, as an hereditary character, the capacity of rapidly extracting from the substratum a food substance, A, essential to ascocarp formation, but is lacking, or weak, in the power to accumulate the equally necessary material, B. Suppose, similarly, that a (—) strain can obtain B, but not A. If two (+) or two (—) strains meet, the nutritive conditions for fruiting are not fulfilled, but, if (—) hyphæ fuse with (+) hyphæ, all requirements are met, and a row of ascocarps is the result.

In the great mass of work on other heterothallic forms, information is available which seems to support this hypothesis. In some of the smuts, fusion does not occur if the mycelia have been grown on media rich in albuminous compounds. In *Glomerella* the (—) strain forms fertile spores only on an appropriate substratum. Both in the rusts and in the Hymenomycetes species occur which can develop fruits from a (+) or a (—) mycelium alone, though more slowly than from the combination of both. In such cases, the hetero-homothallic forms, each mycelium may be inferred gradually to acquire the material which the other can rapidly obtain.

Again, in the Hymenomycetes, we have species, such as *Aleurodiscus polygonus* and *Coprinus lagopus*, which are described as quadrisexual. It

may be difficult to form a conception of a race with four sexes, but a race requiring four or more food substances in preparation for the fruiting period is a matter of common experience. Let the four characters, known as A, a, B and b, which these fungi have been shown to inherit on mendelian lines, represent each the capacity of rapidly extracting from the substratum some essential food, and let every spore contain, as it is known to do, either A or a and either B or b; then the requisite food supply is assured only when AB and ab, or Ab and aB have pooled resources. In other words, for an AB strain the limiting factors are the scarcity of a and b, while the development of an ab strain is restricted by poverty in respect of A and B. If different sporophores develop a different arrangement of limiting factors, the otherwise astonishing fact that mycelia from all the spores of one heterothallic sporophore may be fertile with those from all the spores of another is readily understood.

The higher Basidiomycetes are wholly lacking in sexual organs, and it is impossible to judge whether the heterothallic condition arose, as in Ascomycetes, while these were still extant. A further study of the heterothallic rusts may throw light on this interesting question.

In Ascomycetes account has to be taken of so many peculiar features that one hesitates to suggest any correlation between them. To those who accept the observation of Harper[56] and his many successors that a nuclear fusion in the oogonium is followed by a fusion in the ascus, the simultaneous occurrence of heterothallism and sexuality is at least suggestive. But in the present state of our knowledge it is no more, and the suggestion may lead to another of the blank walls with which the study of fungi is beset. Particularly to be desired is the full investigation of a heterothallic form in which the entrance of male nuclei into the oogonium still occurs. *Pyronema confluens* and *Pyronema domesticum* are uncompromisingly homothallic, male and female organs and normal fruits being found in single spore culture. There is some hope of *Ascobolus magnificus* or *Ascobolus carbonarius*.

Since heterothallism occurs in all the main groups of Basidiomycetes and Ascomycetes, it may be inferred that its origin is remote, and the question arises whether the phenomenon, as elucidated in these fungi, bears any relationship to the heterothallism of the Mucorales. In *Mucor* and its allies the branches of (+) and (—) mycelia grow towards one another and become attached, the procedure up to this stage being very similar to that in *Humaria* and, I should judge, in the Hymenomycetes also. The result of contact, however, is the development of sexual organs at the point of union. This differs from *Humaria*, in which only female organs are formed, and those on a neighbouring branch; and from the Hymenomycetes, in which sexual organs are not produced. Moreover, in the mucors, open communication does not occur between (+) and (—) strains till their gametangia are mature, and, if the distinction between them be nutritive, the nutritional deficiencies of each mycelium must at first be supplied by diffusion. It is true that the archicarps of *Humaria* develop up to a point without mycelial fusion, but in *Mucor* the presence of two mycelia is necessary before gametangia appear. As an argument for the sexual nature of the (+) and (—) strains in the Mucorales, Satina and Blakeslee[57] have lately shown that, with the $KMnO_4$ and Manilov

tests, a distinction can be drawn between (+) and (—) strains, the former, like the female plants of dioecious angiosperms, being the stronger reducers. It may be suggested, as a working hypothesis, that nutritive heterothallism arose in the ancestors of the higher fungi after their mycelium had become septate, and was made possible by the prevalence of mycelial fusions which distinguishes septate forms.

Sex and Nutrition.

But, after all, if heterothallism in these fungi is a nutritive phenomenon, does it thereby differ from sexual fusion? Van Rees[58] in 1887 and Dangeard[59] in 1899 suggested that syngamy first arose as a process of reciprocal cannibalism or autophagy. Gametes were characterised as hungry cells which lacked the means to continue their development unaided, and were able to do so only when two had pooled their resources. Thus we have the facultative gametes of *Ulothrix*, which function as zoospores when conditions are good, and the gametes of *Synchytrium*, which are zoospores retarded in development. In *Reticularia Lycoperdon*, Wilson and Cadman[60] have shown that, after the union of two gametes, three to eight similar swarmers are drawn into the mass and coalesce; their nuclei degenerate and they serve as food, but the process in its early stages is very like the gametic union. Syngamy may be, in fact, in some of its aspects, a form of nutrition, but that is very far from saying that all forms of nutrition are syngamy. The fungi, in addition to the wide variety of their sexual process and their many saprophytic and parasitic means of obtaining food, have given evidence of a special development which, partaking of some of the characters of each, may possibly throw light on the peculiarities of both, and, in so doing, may provide a clue to the significance of the primitive sexual fusion.

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EDUCATION: THE NEXT STEPS.

ADDRESS BY

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THE chief advance made in the first quarter of the twentieth century has been that the nation as a whole has been converted to belief in the value of education. When the century began there were still very many who had received little or no schooling in their youth, but had won their way, not without a considerable measure of self-satisfaction, to substantial positions. That perhaps legitimate pride was based on a certain misunderstanding of the values of life, and it involved the fallacy vividly exhibited by a certain local millionaire of my acquaintance, who was asked to support the movement for the establishment of the local university. 'University,' he said: 'what do you want with a university? I left school when I was thirteen, and look at me.' Now it was just because we *were* looking at him that we desired the means of higher education to be at the command of the community, though at that particular interview it was hard to say so. To-day, nearly a generation later, that particular type—a type usually of sturdy independence, strong character, and material outlook—has largely been gathered to its fathers; there have been twenty-five years of constantly extending further education; the War has taken place. Opposition to education as such, at any rate to education after the age of fourteen, is now confined to the National Confederation of Employers' Organisations, and to the farmers, both of which circles are mostly interested in the continuance of the supply of young labour under the conditions to which they have been hitherto accustomed. But they represent now a definite minority of the nation, which as a whole is unwilling to think of a large mass of its members as merely raw material to be utilised in its course from the school to the scrap-heap; it believes that each boy and girl has a right to be trained as an individual. There flourishes to-day a living and growing belief in the value of human personality; it dominates all that is best in our education, and I believe it will soon be unquestioned in any quarter. It must so dominate the general mind if our democracy is to justify itself, if, indeed, it is to survive.

Anyone who studies the growth of our education during the last century cannot fail to be impressed by the fact that it has been developed to meet needs which made themselves felt in practice, and not to satisfy preconceived theories, or a logical perfection. Its history is that of a soldiers' battle: it has been the creation of actual combatants, and not of a general staff. As a result it has all the vitality which comes from

springing direct from the national life, so that the life of the schools is interwoven with that of the people; but as a system it is not logical, and it is not complete. There have been remarkable and successful achievements in some directions, but gaps have been left unfilled in others. It has been well said that the landscape of English education is one of peaks and valleys rather than that of a uniform tableland. It is our business now to think nationally as well as locally, and to apply our minds to the filling up of those valleys, some of them deep, which still exist, and it is the purpose of this paper to indicate what, in the opinion of one who has spent more than twenty-five years in service in one field of our education, are the next steps which we should take if we are to move towards the creation of a system which is really national, and will provide for all the varying and complicated needs of a great nation of the twentieth century.

Right across the path of advance lies a lion, at the moment only apparently asleep, which has already devoured imprudent wayfarers, and may devour more: I need not say that I refer to the existing system of dual control in elementary education. It is as well to know what is the size of this problem. According to the last published figures, those for 1926–27, out of 22,629 public elementary schools in England and Wales, 10,478 were Council Schools and 12,151 were Voluntary Schools; of these 12,151 again 10,457 were Church of England, 135 Wesleyan, 1,196 Roman Catholic, 12 Jewish, and 351 of other types. Taking it another way, by the numbers of children in attendance, there were 4,924,102 in the Council Schools and 2,711,244 in the Voluntary. It is therefore a very large problem, the solution of which cannot be left to time, as is our national way when we are in the presence of a difficulty; for, while it is true that the number of Council Schools tends steadily to increase, and the number of Voluntary Schools to dwindle, yet the process is so slow that it would take very much more than a century before the Voluntary Schools became negligible. The position is this: that the Act of 1902 left the buildings of the Voluntary Schools in the possession of the denominations, and the religious teaching of the schools under the authority of the school managers, who retain also the right to appoint the teacher. Those who to-day have to organise the whole of education in any district find themselves hampered at every turn by the fact that they do not control all the schools. If, on the authority of the Education Act of 1921, they want to take the older children from a number of schools and group them for better teaching into one, they may find that the non-provided schools will not part with the very children for whom the system is designed. They may desire to reorganise, re-equip or rebuild a school, and find that the managers may very probably not possess the means, and in some cases not the will, to bear the expenditure involved. They may be aware, as in some cases they are aware, that the buildings to which the children have to go are ill-equipped, badly planned, far below the standards of the present day, but there is very little which they can in practice do to remedy this state of affairs. Even if they are willing to build a totally new school they have to face the fact that, without the good will of the managers of the non-provided school, they may fail to obtain the attendance of a proportion of the children large enough to justify the expenditure. Thus there is at present neither simplicity, economy, nor efficiency. On the denominations

themselves the system plainly imposes burdens which are in general beyond their means. A settlement of the question is demanded in spite of the fact that any attempt at a solution brings the solver up against what some would call religious conviction and others sectarian prejudice. Nevertheless there is more general good will in the air and a greater spirit of reason, and we ought to go forward. I submit that advance can go forward on lines which have been proposed, and found pretty general support, that the Voluntary schools should be transferred to the local authorities, who in return should allow at certain times and on certain days facilities of entry. Religious instruction would be given at definite periods, during which, if it were desired, certain children could be withdrawn for denominational instruction to be provided by the denominations. So far as Church of England and Nonconformist schools are concerned, I do not believe the withdrawal would in practice prove necessary or desirable, for I think that a very strong majority of the nation desires that the basis of all our education should be religious and Christian. These religious bodies are near enough together to arrive at a concordat as to the syllabus of religious instruction which should be followed, and the principles of the denomination could well and fitly be taught in the Sunday schools. I would submit that the educational enthusiasm and beneficence of the denominations could from their own point of view be most usefully directed to the provision of a certain number of schools for post-primary education and of training colleges for teachers. At any rate the scheme which I have thus briefly outlined is not one which disturbs the position and functions of teachers on the one hand, or one which need create friction between the churches and the local authorities on the other. But it does give the local authority effective control over buildings and organisation, and that is a necessary condition if further advance is to be made.

That further advance is outlined in the Report on the Education of the Adolescent, which has come to be known as the Hadow Report; since its publication it has commanded an unusual amount of support and interest. I give my unqualified adherence to the proposals which it makes, though I do not agree with the nomenclature which it suggests. Primary education should in future be a stage which ends at about the age of 11+, and this for the best of reasons, because at about that age childhood closes and the first beginnings of adolescence set in. A second stage of education should therefore start at this point, going on for the majority to 15+, for many to 16+, for some to 18 or 19, this stage being regarded as a single whole, designed to meet the needs of the adolescent, and therefore containing within itself a considerable variety of type. This is not simply a question of adding one year to the course as it exists at present: it means rethinking the whole of our education on a psychological basis, and designing the primary course for the years of childhood, the post-primary courses for the ensuing years. It means as an ideal that all children would go forward after eleven on parallel lines, following the course best suited to each. The Hadow Report therefore states in its second conclusion that, 'while taking the country as a whole, many more children should pass to "secondary" schools in the current sense of the term than pass at present, it is necessary that the post-primary grade of

education should include other types of post-primary schools, with curricula varying according to both the age up to which the majority of pupils will remain at school and the different interests and utilities of the pupils to which the bias and objective of each school will normally be related.' They envisage, therefore, besides the secondary schools of literary and scientific type, selective central schools with a four-year course, and a practical trend in the last two, non-selective central schools, which may exist either by themselves in some areas, or in other areas side by side with the selective schools, and a variety of other arrangements, which I think they only insert in their report because they realise that there must be a temporary period of makeshifts. Quite rightly, as I think, they do not believe that this system, if established, would hamper or cripple our already existing secondary schools, for the desire for education, once it is established, grows of itself. Quite rightly they realise that the education of adolescence is something wider than that which is given through books alone, and the new schools, while they begin with their eleven-year-old pupils in much the same way as the secondary schools, will always seek to develop the hand and the eye, and in their last two years will develop a practical bias.

There is an immense gap which the promoters of this report seek to fill, and only those who have studied facts and figures know how large it is, so large, indeed, that it prevents us from making any claim at present that we have a system of education which deserves to be called national. In any one year the total school population is very slightly above 700,000. At the age of 14+ there are at least 300,000 children who are outside the system altogether, and receiving no continued instruction; at the age of 15+ this figure has risen to 520,000. This means that the effort and the money which have been devoted to the training of those children up to the age of 14 are in very considerable measure wasted; and though I have not time to argue it now, or to advance the evidence, here in this gap may be found the reasons for much of the unemployment, and still more of the unemployability, which exist within our society to-day. It is of the most vital importance that those years of adolescence should be safeguarded by all that is of inspiration and of good report. Which of us would willingly allow a child of his own to pass to the work of the world at this age without further help? Not one of us. It is not a question of the interest of employers, or of the interest of parents; it is a question of the interest of the child, and of the nation, whose main wealth is the men and women which it produces. And since, if it were a matter of the interest of our own children, we could only answer that question in one way, it seems to me a plain matter of social duty to strive to bring it about that the same safeguards and help should exist for all, and that we shall not continue to neglect a full half of the children who are born into our country.

But before I pass from the region of primary education there are a few further points which I should like to make, though I must make them briefly. We take our children into school at the age of five, a year earlier than any other country, and after a good deal of past blundering we have developed in many of our infant schools institutions which seem to me to be of peculiar merit. In them the children are active, not passive, happy,

and not dull: the atmosphere is that which is proper to early childhood, an atmosphere of freedom, spontaneity, and joy. I should like to see the policy steadily followed of developing and increasing the number of these admirable places. I have no doubt, too, that the policy will be steadily followed of reducing the size of classes in the primary school. I need not labour this, for to this audience it will be obvious that a teacher confronted by sixty, seventy or more pupils cannot follow the same methods, or seek the same ends, as the teacher who deals with thirty-five. The teacher of the large class can seek only discipline and a certain amount of mechanical accuracy; as the numbers fall he can begin to treat his pupils as individuals. He can develop those methods, for instance, which I believe are admirably suited to the stage of the primary school, which are associated with the name of Miss Charlotte Mason, and the Parents' National Educational Union. Promising experiments have been made on these lines in Gloucestershire, Kent and elsewhere, and during our sessions we shall hear more of them. Other experiments also can be tried so long as the teacher is not overborne by numbers. But of primary education as a whole—and I am speaking of the stage that ends at 11+, not at 14—I would say that it is no longer the region of the three R's; it is the region of another trinity, the hand, the eye, and the voice. It is the business of the primary school to teach the child to see and observe, to make and to do, and to speak and to sing. And then the child will be much more fit to enter into the great inheritance of the world, with more capacity for true happiness, and more capacity for true intelligence.

In passing from this digression once again to the consideration of post-primary and secondary education, it is in place not to omit the mention of one other administrative reform, and that is the rearrangement of local authorities so that in any given area there should be one authority for the whole work of education. At present there are 318 authorities for elementary education and 145 for higher education; the mere mention of the fact shows that in many districts it is impossible to organise the education as a whole. Clearly the areas should be wide, for to-day communities spread over great distances, and their members sleep in one place and work in another; not only in education it is beginning to be found that units which are too small do not make for cheapness or efficiency.

To turn to the problems of secondary education proper—by which I mean education of boys and girls up to the age of 18—it is advisable first to survey the present position and to see how that position has arisen. The public schools and the great day schools of the nineteenth century were inspired both in regard to curriculum and method by Oxford and Cambridge, and they were largely classical; a reaction against this undue narrowness led to the experiment of the Organised Science Schools of the last ten years of that century. These in their turn certainly carried the reaction too far, and produced juvenile chemists and physicists without culture or general education. In 1907 the Board of Education issued its first regulations for secondary schools, and sought something broader than either of these two rival institutions; they established a four-year course in which English, geography and history, at least one language other than English, mathematics, science, and drawing should be studied,

together with manual work, physical exercises, and, for girls, housewifery. As that course has been worked in practice in the last twenty-five years, it has been in the main academic in spirit, and the important subjects have come to be the native tongue, the foreign language or languages, and mathematics and science; the schools have continued to look to the universities, and to the development of those advanced courses which lead up to university studies. All this effort has been directed and stabilised, and some would say stereotyped, by the setting up of the system of school certificates, for which in England and Wales eight university authorities examine. All the secondary schools, therefore, have in the main the same outlook, which is primarily that each pupil should at the end of the first stage of the course be able to matriculate at a university; the school certificates have been brought into relation with the matriculation examinations, and the system is now organised in all its details.

Meantime the number of schools, and the number of pupils at each school, have greatly increased. In 1904 in England the number of secondary schools for boys, for girls, and for boys and girls together was 575; there are now 1,184 recognised for grant by the Board of Education and 305 recognised as efficient, but not eligible for grant. In 1904 the number of pupils was 97,698; in October 1927 it was 349,430, and if you add the 57,655 in the schools not eligible for grant you get a total of 400,000 boys and girls who are in England pursuing a course of secondary education. Now the reason why I have troubled you with these figures is to point out that, while the content of secondary education has not changed, and remains academic in spirit and outlook, the number of schools has more than doubled, and the number of pupils has increased by more than four times. To put it clearly in another way, in the first year in which the school certificates examination was held, there were 14,232 candidates; for the last one for which figures are available there were 54,593, again very nearly an increase of four times.

The result of pouring all this mass of new material into a single mould has produced a slowly increasing volume of protest, but those who protest are much more sure in describing the symptoms of the distresses of the secondary schools than they are in pointing to their cause or in finding the cure. It is said that there is a good deal of overstrain among the pupils of the secondary schools, particularly among the girls, and that for the average the effort of reaching a satisfactory level in English and English subjects, in a foreign language or languages, and in mathematics and sciences is too much. That this is so is shown by the fact that when the examination was established it was supposed that nearly all would be successful at the end of their course in obtaining a school certificate, but as a matter of experience less than two out of three have been able to do so. It is alleged that the examination hampers the freedom of the teacher, who during the whole four years' course can never turn aside to browse in the pleasant paths of literature or to pursue interests common to himself and his class, but must concentrate the attention of his class and himself wholly upon what will pay in the examination room. Great schoolmasters of the past are quoted who could never have pursued their favourite methods with success under present conditions. It is asserted

that for many boys, and for still more girls, the present curriculum is unsuitable, that they are not all, or indeed comparatively many, of them going to the universities, and that they ought not to be sacrificed to the interests of the few who do contemplate that course. The question is raised whether as a matter of fact this intellectual training of the girl ought to be the same as that of the boy, and whether the tyranny of imposing the preparatory curriculum of the university upon the girls is not even more unreasonable than it is asserted to be in the case of the boys. On this point the committee which reported on the differentiation of the curricula as between the sexes spoke with an uncertain voice, probably because they knew that there were many feminine associations ready to tear and devour any committee or any individual who said anything which might be taken to imply that women were not the full equals of men, and girls of boys.

The practical outcome of all this is the suggestion that boys and girls should be awarded a school certificate even if they omit a foreign language entirely, or mathematics and science entirely, so long as they make up for it by proficiency in subjects such as music, art, handicraft, housecraft and other subjects of more motley character and more dubious claim. On this proposal the English teaching profession is divided, the Headmasters' Conference and the Assistant Masters' Association being against it, the Headmasters' Association doubtfully in favour, and the Headmistresses' Association and the Assistant Mistresses almost as one woman in favour also. From this state of affairs one can judge where the shoe pinches most, but there is no doubt that it does pinch, and anyone who remembers the figures which I have just quoted will quite readily understand why. There are more boys and girls taking the full secondary course to-day than are either fit for it or fitted by it. The malcontents are quite right in the criticisms which they level against the system and its present results, but they are in my opinion wrong as to the nature of the cure and the method by which they would bring it about.

The standard of secondary education in England is high, and is something of which we have a right to be proud. Its methods and objects are the fruit of long experience and of the efforts of several generations. The boy or girl who has taken a school certificate before the age of sixteen, followed an advanced course, or specialisation in a sixth form, to the age of 18+, has reached a level attained in few educational systems other than our own. I question indeed whether any country is producing boys and girls of as high a level of intellectual excellence and training as those hundreds who go up every year to compete for scholarships and places at Oxford and Cambridge. I believe this to be true of the boys, and it is certainly true of the girls. This system is now built on the general education of the school certificate and the specialised education of the higher certificate, and I hold that it should stand unimpaired, and not be tampered with; for it is far easier to relax a standard than ever to recover it. To say that every boy and girl who goes to a secondary school for four years should be awarded the same certificate, whatever subjects they may have studied and offered, is to say that things which are not equal to one another are equal to the same thing; it is to say that the boy who has been successful in English, history, geography, Latin, French, mathe-

matics and science is *primâ facie* the same article as the boy who has been successful in English, general elementary science, drawing, handicraft and shorthand, or the girl who has offered English, botany, music, drawing and needlework. I am not representing either course as better than the other; one may be right for A and the other for B. I hold no brief to argue that the high-brow is better than the low-brow, or the blue stocking than the flesh-coloured stocking. All that I maintain is that they are palpably not the same, that it is illogical therefore to call them the same, and that nothing but confusion will result from calling them the same. It may be democratic and in accordance with the spirit of the age to hold that we are all the same as one another, and ought therefore to be labelled with the same labels; but no man who has taught a class for one term can really hold that nature gives any warrant to such nonsense. Surely the logical course is to award two kinds of certificate, one which shall fulfil the academic conditions and maintain unlowered the existing system which causes no difficulty to the boy or girl of average academic ability, and the other which shall be a proof that the boy or girl has taken at school that course of education which in the particular case was the most fitted.

I would therefore have in any secondary school these two types definitely recognised to be different, not superior or inferior, the one to the other, but different. It would be recognised at the school-certificate stage by the one type sitting for the school certificate awarded as it now is, and the other for a general certificate which shall show that they have made good use of a good and sensible type of education. If they stay at school the one type will continue to go on to the higher certificate, again organised as it now is, and the other to a second certificate, which shall again test the subjects of a quite unspecialised education, designed to meet the individual need in each case. There will then be a good deal of variety inside secondary education, and when the central schools become more numerous and more organised, and the modern schools come into existence in increasing quantity, there will be a good deal of variety outside the old secondary schools as well. And when you consider the variety which must exist among that more than half-million boys and girls with whom we shall have to deal, I think you will agree with me that the more variety there is the better.

Even so my discussion of the problem of the right curriculum for the higher forms of the secondary school is not complete. In saying that the standard should remain unimpaired, and not be tampered with, I have in mind the work of the best boys and girls. But many more than the best go on to the universities, and it is right that they should do so; I am not convinced that any of these should attempt specialised study before they enter the classes of the university. On the one hand the colleges of Oxford and Cambridge, through their open scholarship examinations, enforce on the schools the attempt to reach a very high standard along narrow lines; some universities, by allowing their intermediate examinations to be taken through the higher certificate, confuse the courses proper to themselves and to the schools; some universities admit their students too early; the higher-certificate courses themselves often involve specialisation built on a very slender foundation of general

knowledge. On the other hand many professors and university teachers are loud in their condemnation of the state in which their pupils come to them, with minds ill-balanced and ill-furnished. I submit that this region of the last two years of school is insufficiently explored, and the nature of the work that should be done by the average student not thought out. I submit further that it is a matter which might well engage the attention of all the universities of the country in conference. They have perhaps no common mind, but I do not know that they have attempted to arrive at one: they have never clearly stated what they want; they have never faced the fact that through their scholarships they make extreme specialisation necessary, and through their professors complain of the result. I regard the matter as urgent, for as chairman of the Secondary Schools Examination Council I know that the curriculum and the examinations proper to this later period of school life stand in great need of definition, and that in proceeding to the work, which cannot long be deferred, we have no clear guidance from the universities as to what they really want.

However, it is not only in the secondary schools that some thinking needs to be done about the requirements of the immediate future; there is also some advance that needs to be made after due thought in that very complicated field which is known as technical and further education. There has just lately been issued the second part of the report of the Committee on Education and Industry in England and Wales, to which I would commend this audience if they would like to go deeply into the matter. In this department of education the next steps which require to be taken are all of them steps to secure better contact with other branches of the educational system, and with industry and employment. Technical education is a field which has been developed all by itself, and in isolation from almost everything else. Each part has grown to meet a need, and usually a local need. It is cut off from the elementary education which precedes it, for elementary and technical education have been controlled by different departments of the Board of Education, and it is cut off from the university education, which in the case of the best students ought to follow. There is frequently a gap of one, two, or even more years between the end of the elementary course and the beginning of technical instruction, and that instruction is frequently sterilised by the fact that students have to come to it tired, late in the evening, and in the centre of cities. Finally, there is need of much fuller contact, of more mutual knowledge and sympathy, not only between technical education and industry, but also between all forms of industry and commerce and all forms of education. There ought to be a full inquiry into this difficult and complicated problem; educationists ought to know and consider more thoroughly what is wanted, and employers ought to take much more trouble to find out what is being done. May I quote in this connexion a paragraph from the recent report of the Committee on Education and Industry with which I thoroughly agree? 'We do not consider,' they say, 'that educational policy should be determined by industrial requirements, however legitimate in themselves. What we do feel most strongly is that in the interests of the boys and girls, quite as much as in the interests of industry, educational policy, and still more

important its application in detail, ought not to be settled without full knowledge of occupational conditions, prospects and needs. It cannot be said that educational administrators are in as close touch with trade and industry as they would wish to be at this important stage in educational history. We are therefore forced to two conclusions. In the first place, any measures which can be taken to secure the contact which everyone desires should be taken with all possible speed, before the educational position becomes so solidified that any modifications, however desirable, will be extremely difficult, if not impossible, to make. In the second place, local authorities and all others concerned should obtain, so far as is possible, the views of representatives of trade and industry, employers and workers alike, before committing themselves to any reorganisation which might have direct or indirect effects on industrial conditions. The connexion between school arrangements and circumstances of employment are not always apparent at first sight, and too great care cannot be expended in investigating the industrial implication of educational changes.'

There is a large question of very general interest which I can state, though I do not know that I can supply an answer. What is the proper part which formal and external examination should play in our educational courses? Examinations at the present time play a very large part. In a great many places there is competition and examination for scholarships and for free places at the secondary schools; some four years later there follows the school certificate, theoretically for all. One or two years later follows the higher-certificate examination, and then there are for some all the university and professional examinations in prospect. Entrance to the public schools is obtained by an examination known as the common entrance examination, which is said in some cases to be competitive, but in all cases involves the reaching by the candidate of a certain definite standard. Competitive examination admits to the Army, Navy, and the Civil Service. The system is so thorough and so universal that the victim, if that is the right word, may never be out of the shadow of an examination from eleven years old to twenty-three, or even later. It is argued, first, that this gives almost inevitably a totally wrong view of knowledge, and makes a boy or a girl from school days on feel that his or her object is not to study a subject, but to acquire the capacity to answer on paper examination questions about it, and that therefore, once examinations are over, he or she learns no more. It is argued, secondly, that the teacher's freedom is destroyed, since he has to teach his subject not in the best way, but in the way which will pay best in the examination, and that the more inspiring, original, and fresh he is in presentment, the less he is likely to succeed on a mechanical system. It is alleged, thirdly, that the system is really unsuccessful, that it picks out for honour those who have the examination faculty and can write fast and to the point, but that, judging by what happens in after-life, it does not really pick the best men and women, and those who will go furthest in their study.

There is a certain amount of truth, but a good deal of unreasonableness and lack of practical common sense, in all this attack which is so frequently made to-day. My own profession, the schoolmasters, are not inconsistent, though the schoolmistresses dispute the palm with them, for they insist

on a certificate to mark the successful completion of all their courses, and do not rest until all the subjects which they teach have been brought, for instance, within the ambit of the school certificate. The subjects which of all others ought to be the most free, and are in my opinion in their own interests least examinable—music and art—are, I suppose, the means for awarding more certificates by examination than any other, and the blame for this I lay largely at the door of my professional brothers and sisters. It is not, I think, seriously true that teachers are cramped by the examinations; on the whole examinations follow the school curricula, and do not control them; the teachers, moreover, are well represented on the examining authorities, and can make their voices heard. It is not possible to say whether a boy or girl knows a subject save by asking questions; these must be the same for all, answered under the same conditions in the same time, and that makes a written examination necessary. No one suggests that examinations are more than they are, a very human and sometimes fallible means of finding out whether a candidate knows what he ought to know, and no one in his senses claims that they pick out the person who will be ultimately the most successful. What is true is that in early years they tend to dull the edge of the desire for true knowledge, and that throughout school life there are plenty who are quite incapable of showing on paper what they have in their head; they are not fools, though they may be written down as such, but they are bad examinees. Moreover, in any system of examination which is more or less universal—as is the case with the school certificate—we have to think of the dull and of the slow developers, who suffer badly when they are crammed and forced to an unnatural level.

I believe, therefore, though the time is not yet, that the right course will be to abolish all external examination for the average boy and girl, though leaving it as the avenue to the universities and the professions. In the case of the average boy and girl the properly inspected and efficient school will issue its own certificate that A or B has attended for four or six years as the case may be, and has reached a satisfactory level of performance. The power to make such an award implies a high standard of professional honour, and perhaps a higher level of efficiency than yet exists, but it would enable the schools to teach a pupil what he could learn, to teach him in the right way, and not drive him in the wrong way to a wrong standard. The mere size and complication of the examination system will tend to break it down. Doubtless 55,000 candidates have sat for the school certificate this summer, each doing six, seven, or eight papers; the number of qualified examiners free to undertake the work is very limited. In another twenty years there may be 100,000 candidates, for the Hadow Report asks for a special leaving examination for all the pupils at those modern schools which it hopes to see established. Certainly the question will become acute, whether so great an effort will be repaid by any advantage which can accrue from the issue of tens of thousands of certificates each year, certificates which state that the holders have in effect reached a very moderate standard of knowledge, such as you might expect from an average person of their years. Would not the issue of a similar statement by a responsible school have a precisely equal value?

To see the examination system at its worst it should be studied in the common entrance examination to the public schools. This examines four to five thousand candidates yearly, and is designed to ascertain whether those thirteen-year-olds know enough English, scripture, history, geography, Latin, French, arithmetic, algebra and geometry to be admitted to the bottom form of a public school. Much of the boy's future depends upon the result of this examination, for the doors to the schools which he desires will remain locked if he does not qualify. The object, therefore, of what is a most expensive form of education and of what should be the best, carried out as it is with small classes and in good buildings, is to enable little boys to answer questions on paper with great rapidity, and to switch their small minds with accuracy from Genesis to Ivanhoe, from Henry VIII to the causes of rainfall, from quotations to problems, from Latin to French, and so on, for two momentous days. The bright boy finds it easy, the average boy in many cases, the dull boy in all cases, finds it terribly hard. The result on the teaching is remarkable, for there is a handbook issued, which commands a large sale and a free use in many schools, which has reduced the whole thing to cram by analysis of all the past papers. I have in my possession a leaflet which bears the inscription 'To the Preparatory Schools is dedicated this sample of the Common Entrance Handbook in the sincere belief that the latter will prove a boon to all who possess it.' David and Jonathan, Publishers, 60 pages, price 5*s*. I turn the page and find all the sovereigns of England ranged in order according to the frequency of their occurrence in the last thirty-three papers, from Victoria, ninety-seven, to Edward V, who has failed to score; the same with English Literature, from Westward Ho! with fourteen occurrences to Rip Van Winkle with one, Idylls of the King, twenty-one, to John Gilpin, one; it is very thorough, for it treats languages and geography in the same way. Truly the preface may well say that the handbook was written not with a view to publication: it was written to supply a need. That need was the necessity of cramming, and not educating—a process degrading to the teacher, hurtful to the taught, and a cause for hanging the head to all who are responsible for the system which has produced this travesty of our art. It is no surprise to learn that there are schools where the boys read no authors, but only do examination papers; read no history, but memorise answers about names, and treat literature and geography in the same way. I conceive that there is no method of reform save the abolition of so indefensible a system, and I believe that it is, or ought to be, an educational axiom that there should never be any examination of a child under fifteen save by his own teachers. If anyone doubts this I would ask him to estimate the improvement of elementary education in this country which has taken place since payment by results was done away with and the inspector's examination was abolished.

I must draw to a close. Whatever reforms of administration, whatever changes of curriculum, whatever increase of expenditure are approved, the last word lies with the teachers, and all depends on the spirit which animates them and the ideals which move them. This country is committed to the experiment of unrestricted democracy, ideally the highest form of government if the quality of the citizens is good, in practice

capable of being the worst, where the citizens are uneducated and incapable of discerning the true values of life. Everything seems to me to depend upon whether the teachers in the next generation rise to the full measure of their responsibility and opportunity, whether they carry through every part and parcel of our educational system the highest and truest English tradition, that education is more than instruction, that character counts for more than brains and lives more than learning, that the true basis of life is religious, and the only real values spiritual. I would say that the main end and aim is to train boys and girls for service to the community, and to make clear that their lives can be lived in this spirit, whether they are tradesmen or merchants, engineers or manufacturers, clergymen or doctors, or followers of any career whatever, and that the only life deserving of contempt is the life that contributes nothing, or contributes evil, to the common stock. We have a fine traditional method to follow, which has been handed down to us from the best of our predecessors; we can build our school lives on fellowship and the sense of honour, on the team-spirit and not on individualism. We can point our pupils forward to the quest of seeking to establish among the citizens of this country a more equitable division of the things that matter, not by the self-destructive method of class-war, but by the mutual help of classes. We can save them from the fallacy that money is the thing that matters most, for we can show them that the values of eternal life are among us now, and now can be sought.

There is no nobler calling than that of the teacher, and the hope of the future lies in this, that none can escape the teacher's influence. The highest education is the gift of personality to personality, where in freedom one leads, and others are fired to follow; and this cannot occur unless schools are free and individual, and the teachers within them no less free to develop and give the best of which they are capable. Education can and must be organised in Whitehall and the county town, but it cannot there be given; it can only pass from living men and women to living boys and girls, where each is known to each. This personal relation based on freedom is the most precious tradition that has come to us from the greatest of the past, and any advance of organisation and extended scope would be too dearly bought if it brought into question, or rendered impossible, the spontaneity and independence without which no school can be great.

THE LIVE STOCK INDUSTRY AND ITS DEVELOPMENT.

ADDRESS BY

J. S. GORDON, C.B.E., D.Sc.,

PRESIDENT OF THE SECTION.

On looking over the Presidential Addresses delivered since the inauguration in 1912 of the Agricultural Section of the British Association, I noted that so far the Live Stock industry had not been formally discussed by this section. As at the moment those engaged in agriculture are giving far more consideration to the development of the live stock branch of the industry than at any time previously, and moreover, as Government departments have awakened to the necessity for providing State assistance for the improvement of our herds and flocks, I came to the conclusion that an address on this subject would be not only of interest to the members of the Agricultural Section but, through the discussion which I hope will follow, might lead to the making of some practical suggestions for the further advancement of this, in my opinion, the most important branch of British agriculture.

The Place of Live Stock in Empire Agriculture.

That the live stock industry occupies a predominant position in our agricultural economy is shown beyond question by official statistics. I have examined the statistics of agricultural production in a number of the leading countries of the British Commonwealth, and have divided them into two classes : (1) live stock and live stock products, and (2) crops. The first class includes cattle, sheep, swine and poultry, together with their products, beef, mutton, pork, bacon, milk, butter, cheese, eggs, wool, &c., while the second class comprises cereals, potatoes, hay, straw, flax, grass seeds, fruit, vegetables, &c.

In the case of Great Britain and Northern Ireland the census of agricultural production which was taken in 1925 provides a mass of data for comparing the relative importance of crop and live stock production in these islands. In England and Wales the estimated value of the agricultural and horticultural produce consumed by farmers and their families and sold off farms and other holdings in 1925 was £225,330,000, of which no less than £154,650,000, or 68·6 per cent. represented the output of live stock and live stock products. In Northern Ireland the value of the output of the agricultural industry in 1925 was £15,058,000, of which £11,809,000 or 78·4 per cent. consisted of live stock and live stock products. In passing I may mention the remarkable fact that in Northern Ireland the value of each of the groups comprised under live stock—live stock, milk and dairy produce and poultry and eggs—exceeded the value of the

output of farm crops. The results of the census of production in Scotland have not yet been published, but I feel confident that when they are available they also will show that the value of the live stock industry considerably exceeds that of crops. No statistics as to the total agricultural output of the Irish Free State are available, but at the time of the 1908 Census of Production live stock and live stock products constituted 85·7 per cent. of the value of the agricultural output of the whole of Ireland.

In the Year Books of Australia and New Zealand certain figures are given showing the estimated value of products in those countries. Separate estimates are given for agricultural production (comprising crops and fruit), pastoral production (comprising cattle, sheep, wool and hides), and for farmyard, dairy and bee production (comprising dairy products, pigs and pig products, poultry and bee farming). In Australia during the five years 1920–25 the average value of pastoral, farmyard, dairy and bee products constituted 60 per cent. of the total, while in 1925–26 it amounted to over 64 per cent. of the total. In New Zealand the corresponding figure for the period 1920–23 was 85 per cent. for live stock and live stock products (pastoral, dairy, poultry and bee farming).

The following table shows the value of the output of (1) live stock and live stock products, and (2) crops in the countries mentioned above during the most recent years for which particulars are available :—

Country.	Year.	Live Stock and Live Stock Products.	Crops.	Percentage of Live Stock, &c., to Total.
		£	£	
England and Wales	1925	154,650,000	70,680,000	68·6
Northern Ireland ..	1925	11,809,000	3,249,000	78·4
Ireland	1908	39,057,000	6,517,000	85·7
Australia	1925–26	160,488,000	89,267,000	64·3
New Zealand ..	1922–23	53,982,501	8,365,530	86·6

It is not possible to show the value of live stock and crop production in other portions of the Empire on account of the absence of the necessary statistical data.

Certain general conclusions may, however, be drawn. In Canada figures are available showing the gross agricultural revenue of the Dominion. In 1921 approximately 70 per cent. of this revenue was derived from crops and 30 per cent. from live stock. These figures are, however, not comparable with those already quoted, for no deduction is made for crops used for further agricultural production in feeding to stock. If the net value of crops after deducting the value of the hay, root crops and other fodder crops fed to live stock were shown, the proportion of the agricultural revenue attributable to live stock production would be considerably increased. At the same time, with her large wheat-growing areas, it may be freely admitted that in many parts of Canada the live stock industry is probably of secondary importance as compared with cereal production. Nevertheless it is not without significance that considerable attention is being paid to the improvement of the live stock of the Dominion. In the eastern provinces, moreover, the production of

butter, eggs and bacon is now one of the principal lines of agricultural development.

In the Union of South Africa the live stock industry appears to be on the eve of important developments. The 1924 agricultural census showed that the numbers of live stock in the Union included over 9,600,000 cattle and 32,000,000 sheep. Hitherto the principal agricultural exports have been hides and wool. In 1924 the value of the wool exported was £15,763,953, while the export of hides and skins was valued at £3,196,959. These two items constituted almost 58 per cent. of the total exports of South Africa exclusive of diamonds and gold. On the other hand the export of meats amounted to only £147,207 in value. South Africa has its own peculiar difficulties to overcome, but with the improvement of conditions of animal health together with progress in the methods of refrigeration and transport there may eventually be great scope for South Africa to follow in the steps of other Dominions and develop a trade in meat as well as in hides and wool.

The important position occupied by the live stock industry within the British Empire is apparent from the previous outline. The dependence of our home population upon foreign meat supplies may be visualised from the fact that in 1927 over 700,000 tons of beef and mutton were imported from South America alone. It is thus clear that great scope exists for the development of the grasslands of the Empire as sources of meat supplies competing with both home and foreign producers. Hitherto so far as beef is concerned our home farmers have had to face the most severe competition from the estancias of South America. It seems probable, however, that in the future almost equally severe competition may be experienced from the Dominions.

It is important, therefore, that no effort should be spared to secure the adoption of a policy of live stock improvement within these islands which will enable us to face with confidence both existing and potential competition, alike from the Dominions and from foreign countries.

Let us now consider the position of live stock within the British Isles from another aspect. Has our live stock population maintained its numbers over a series of years and how does it compare with the acreage under tillage for the same period ?

Tilled Area of British Isles.

Between 1871 and 1926 the tilled area of the British Isles declined by 37·1 per cent. The reduction which took place in the different portions of these islands is shown by the following figures :—

Area under Tillage in 1871 and 1926.

	1871. Acres.	1926. Acres.	Reduction. Acres.	Percentage Fall.
England and Wales ..	11,876,723	7,387,335	4,489,388	37·8
Scotland	2,156,954	1,703,431	453,523	21·0
Ireland	3,792,393	2,126,073	1,666,320	43·9
British Isles	17,826,070	11,216,839	6,609,231	37·1

This decline was due to the great reduction in the area devoted to wheat and barley, although the fall in the area under root crops has also been relatively large.

Area under Wheat, Barley and Oats in the British Isles between 1871 and 1926.

	1871. Acres.	1926. Acres.	Reduction. Acres.	Percentage Fall.
Wheat	3,816,345	1,681,480	2,134,865	55·9
Barley	2,606,762	1,412,627	1,194,135	45·8
Oats..	4,351,843	3,771,561	580,282	13·33
	10,774,950	6,865,668	3,909,282	36·28

During this fifty-five year period the area under wheat, oats and barley in the British Isles has thus fallen by nearly four million acres. Meanwhile, the importation of wheat and wheat flour (expressed by equivalent weight of grain) into these islands increased from 2,218,111 tons in 1871 to 6,638,099 tons in 1924—an increase of nearly 200 per cent. During the same period imports of barley increased from 428,450 tons to 1,082,817 tons, an increase of practically 150 per cent.

Hopes have recently been held out that some improvement in the price for cereals may be experienced in the future. The increasing consumption of wheat in Eastern countries has been pointed to as foreshadowing a considerable increase in future demand, while the rapid growth of the population in the United States and in other countries of the New World suggests that the exportable surplus of these countries will be reduced. This may lead to higher prices with increased production at home. On the other hand, the ability of the plant breeder to propagate varieties of wheat, which will open up areas of the world's surface at present incapable of growing this cereal, has to be considered. The recent experience with 'Marquis' wheat in Canada indicates the potentiality of development in this direction.

Live Stock Population.

The number of live stock in Great Britain and Ireland shows, by the following table, a small increase from 1873 to 1926 :—

	1873.	1926.	Increase or Decrease.
Cattle	10,111,651	12,064,570	+1,952,919
Sheep	33,912,155	27,594,688	−6,317,467
Pigs	3,544,713	3,388,000	− 156,713
*Stock Units	15,665,187	16,684,268	+1,019,081

* These units are cattle units—7 sheep and 5 pigs being taken as equivalent each to one cattle unit.

It will be seen from the above table that between 1873 and 1926 the number of cattle increased by almost 2,000,000. On the other hand the

figures show a decrease in the sheep population of over six millions. A very large percentage of lambs is, however, sold before the month of June each year and consequently escapes enumeration. Formerly this trade was insignificant and lambs were kept until more matured when they were included in the official statistics, but the production of, and the demand for, early lamb has steadily increased since 1900.

The figures published thirty years ago are, therefore, hardly comparable with those issued now. In other words, the sheep population in 1926 is greater than the official returns represent, but it would be difficult to say to what extent the early lamb would increase the total figure.

The following table, which has been taken from the Report of the Agricultural Tribunal of Investigation, contrasts the increases which have taken place in the live stock population of the principal European countries. In every instance the increases are decided and in some cases, as for example, Denmark, Holland and Belgium, most striking :—

LIVE STOCK UNITS.

Germany	between	1873	and	1912	shows	an increase	in stock	units	of 22	per cent.
France	,,	1883	,,	1913	,,	,,	,,	,,	15	,,
Belgium	,,	1880	,,	1912	,,	,,	,,	,,	34	,,
Holland	,,	1873	,,	1922	,,	,,	,,	,,	44	,,
Denmark	,,	1871	,,	1922	,,	,,	,,	,,	70	,,
Great Britain and Ireland	,,	1873	,,	1926	,,	,,	,,	,,	6½	,,

At first sight the above table might appear to suggest that we were poor followers. A truer perspective is, however, obtained by considering the changes which have taken place in the stock population per 100 acres of crops and grassland.

PER 100 ACRES OF CROPS AND GRASS.

		Cattle.	Sheep.	Pigs.	Stock Units.
France	1883	13·0	24·0	6·5	17·7
	1913	16·3	17·7	7·7	20·4
Germany	1873	19·5	30·9	8·8	25·7
	1913	24·5	7·0	26·6	30·8
Belgium	1880	28·2	7·5	13·2	31·1
	1912	40·9	4·1	27·5	47·0
Holland	1873	28·7	18·0	7·2	32·7
	1922	37·6	12·2	27·7	44·9
Denmark	1872	18·7	27·8	6·6	24·0
	1922	33·5	6·0	25·3	39·4
Great	1873	19·2	94·6	8·0	34·3
Britain	1926	24·5	79·2	7·7	37·4

It is evident that our live stock population has been maintained in spite of severe overseas competition which has developed since the nineties of last century. In 1890, 134,020 tons of beef were imported into the United Kingdom in addition to 642,596 live animals which, when expressed in their equivalent weight of meat, gave a total import of 310,734 tons. There was little change in the import of beef throughout

the decade ending in 1900, and in that year imports amounted to an estimated total of 378,257 tons. By 1913 they had increased to 499,108 tons, practically the whole of which was imported as dead meat—only 14,743 live cattle entering our ports in that year.

In 1926 imports of beef into Great Britain and Northern Ireland amounted to 721,358 tons in addition to 79,950 cattle (excluding those from the Irish Free State), an increase of over 130 per cent. from 1890.

In the case of mutton, imports have increased from 95,702 tons in 1890 to 274,825 tons in 1926, an increase of nearly 190 per cent.

The position of British Agriculture during the past fifty years may be summed up by saying that arable farming has declined greatly in face of trans-oceanic competition, while live stock has been maintained in the face of almost equally severe competition from the Argentine and the New World.

From the agricultural point of view this indicates that in the British Isles live stock is the most important economic factor and has always been the farmers' sheet-anchor, enabling them during periods of agricultural depression and low prices to pull through until the position improved. During the present depression certain branches of live stock have been well maintained, so far as prices are concerned, compared with pre-war values. I refer chiefly to pigs, sheep, store cattle, dairy products, poultry and eggs. If we compare the average increase in value of crops and live stock including their products for the period 1922–26 with the period 1911–13, as shown by the figures published by the Ministries of Agriculture in England and Wales and in Northern Ireland, we find that in England and Wales there is an excess of fifteen points in favour of live stock and live stock products as compared with tillage, the corresponding figure for Northern Ireland being twenty-six.

Index Figures of Prices of Live Stock and Live Stock Products and of Crops.

1911–13=100.

1922–26. Live Stock and Live Stock Products.			1922–26. Crops.		
Product.	England and Wales.	Northern Ireland.	Product.	England and Wales.	Northern Ireland.
Eggs	170·3	164·9			
Butter	159·9	185·6	Wheat	150·5	162
Fat Cattle	150·6	150·1	Oats	136·5	130·9
Fat Sheep	183·3	184·0	Potatoes	180·7	139·6
Fat Pigs	166·5	177·0	Barley	141·1	—
Poultry	171·6	—			
Store Cattle	—	160·5			
Average	167·0	170·4	Average	152·2	144·2

Advantage in favour of
Live Stock .. .. 15 points 26 points

The same trend of affairs is to be seen in imported produce. A comparison of the pre-war and post-war prices of Manitoba wheat, Argentine beef and New Zealand mutton gives the following figures :—

Year.	No. 1 Manitoba Wheat per 480 lb. Liverpool.	Argentine Beef per 112 lb. London.	New Zealand Mutton per 112 lb. London.
	s. d.	*s. d.*	*s. d.*
1913	35 11	37 6	38 1
1923	45 9	52 0	85 1
1924	53 6	64 6	82 5
1925	62 2	71 2	85 3
1926	58 6	65 4	67 7
Average 1923–26..	54 11¾	63 3	80 1
Increase over 1913	19 0¾	25 9	42 0
Per cent. increase in price	53 per cent.	68 per cent.	110 per cent.

The strong tendency during a period of agricultural depression for price levels to rule more heavily against crops than stock and stock products is not a new feature. It is not without interest and significance to notice that, during the agricultural depression which followed the Franco-Prussian war of 1870, the Danes altered their whole system of agriculture and specialised in dairying, pigs and poultry, because they realised that the fall in prices of good animal products was considerably less than the fall in cereals. This change to concentration on animal products did not, however, reduce the area of land under the plough, but rather increased it, as the crops were converted into live stock products instead of being exported. Since 1880 the cow population, which was then 900,000, increased to over 1,300,000 in 1914, and only one-seventh of the food consumed by the animals—chiefly foods of the protein-rich class—is now imported. The Danes have given practical recognition to the fact that arable farming supports more stock than grass farming, and that stock farming is the real basis of crop farming.

Whilst it is generally realised that as civilisation advances there is a change in human food from the coarser cereals such as rye and oats to maize and wheat, it is important to remember that advances in the standard of living are accompanied by increasing consumption and improvement in the quality of animal products.

Taking, therefore, a wide view of agricultural production, I am confident that as far as the British Isles is concerned the future lies with the stock and stock product branch of the industry. I do not for one moment envisage a ranching country because I am convinced that by concentrating our energies on stock farming we will bring more and not less land under the plough. Indeed, I would go so far as to say that we cannot hope to remain an arable country if we continue to market our cereal crops as such. If, however, we bend our energies in an organised manner to the production of stock and stock products, a steady increase

in our arable acreage will be the inevitable consequence, and British agriculture will not only have a future but will be able to provide a steadily increasing proportion of our national food requirements.

Changes in the Live Stock Industry.

For many years attention was directed mainly to improvement in shape or conformity of flesh-producing animals and in the production of animals which would carry more flesh, especially upon those parts of the body which yielded meat of the highest value. Great attention has also of recent years been directed to early maturity and quality in the production of beef, mutton and pork.

In the case of dairy cattle, high yields of milk and butter-fat were the chief aim, and, in poultry, large egg records.

The change in live stock (cattle, sheep and pigs) during the past thirty years is extraordinary, and is directly attributable to the influence of pedigree sires in the development of fine quality and early maturing animals.

In the British Isles during the seventies of the last century cattle—chiefly 3, 4, 5 and 6 years old—were slaughtered for beef; from 1890–1910 it was usually 3 and 4 year olds—the 5 and 6 year old cattle having practically disappeared; and from this period to 1920 the age became reduced to 2 and 3 year olds, while now there is a considerable and growing demand for beef cattle from 12 to 18 months old.

Between 1871–75 and 1921–25 the proportion of store and fattening cattle in England and Wales under 2 years of age increased from 58·6 per cent. to 69 per cent.

This great alteration in the age at which animals are slaughtered is mainly due to the steadily growing demand for small joints of beef which has arisen since the Great War, and also to the desire for a rapid turnover.

Similar changes have taken place with mutton. Formerly the demand was for 2 and 3 year old wedders; now it is almost entirely confined to lambs and yearling wedders.

The demand for small joints of mutton has increased so much during recent years that large areas of pasture in Great Britain and Northern Ireland, which formerly carried 2 and 3 year old wedders are now stocked entirely with breeding ewes or 1 year old wedders. Two and three year old wedders are almost animals of the past.

This growing request for small joints of mutton is also influencing breeders of commercial sheep in their selection of breeds. In certain areas in Great Britain and Northern Ireland Black-Face ewes have become extremely popular, even in lowland sheep districts, and are being mated with Border Leicester rams, because the joints of the progeny, being small and of fine quality, command a higher price per pound than those of the larger breeds.

Thirty years ago pigs were usually 12 months old before they were ready for the bacon curers; to-day they are being killed at from 6 to 7 months old.

In the United States of America exactly the same changes have taken place. Mr. Edward N. Wentworth, director of Armour's Live Stock Bureau, Chicago, writing in the *Monthly Letter to Animal Husbandmen,*

states that '1894 practically marked the beginning of the passing of the aged range steers, due to the rapid introduction of pure-bred bulls which contributed the ability to make market weights and finish at increasingly younger ages.'

Further evidence of this change in the United States of America may be found in the data from twenty-nine States in the 1920 and 1925 census. This comparison is shown in the following table :—

Beef Cattle in 29 States.				
Year.	Breeding Cows.	Other Beef Cattle.	Total Beef Cattle.	Total Slaughter in the whole of the United States.
1920 ..	4,672,841	8,382,972	13,055,813	13,885,000
1925 ..	5,663,275	7,679,672	13,342,947	14,705,986
Increase ..	21·2%	−8·4%	2·2%	5·9%

The significance of the foregoing figures is that the older fattening cattle decreased by 8·4 per cent., the breeding cows increased by 21·2 per cent., and the total number of beef cattle increased by 2·2 per cent., while at the same time the total slaughter for the whole of the United States increased by 5·9 per cent.

The decrease in average age really increases the effectiveness of the live stock population.

Dealing with the change in market ages in the United States, Mr. Wentworth records that 'from 1895 up to the war there was some reduction in age due to the rapidly increasing use of pure bred sires in the beef-breeding grounds of the range country. . . . Since 1921 there has been a marked reduction in the age of cattle slaughtered if we exclude the dairy type and the breeding cows.' It is estimated that the decrease in the average age of beef steers at Chicago from 1921 is from 12 to 14 months, although some authorities put it as high as 18 months. The reduction in age from 1895 must, therefore, be somewhere between 18 and 24 months. Pigs will average from 4 to 6 months younger than 25 years ago, while sheep will average a full year younger.

Dr. R. J. McFall of the Massachusetts Agricultural College holds the view that productivity in cattle, sheep and swine has been greatly increased, due to the more rapid rate of turnover resulting from the modern practice of marketing lambs instead of sheep, baby beeves instead of older steers, increased numbers of calves as veal, and pigs at an age of from 6 to 8 months instead of 10 to 14 months, as was characteristic twenty-five years ago.

Market Weight of Live Stock.

The average weight at which cattle are slaughtered in England and Wales is estimated to have decreased by 6 per cent. since 1913 and during the last thirty-five years from 10 and 12 cwt. to 8 and 9 cwt. In the United States the decrease is from 10 cwt. to between 8 and 9 cwt. in the same period. From an economic point of view the most

striking feature is that, although the reduction in age is considerable, the decrease in weight is comparatively small. This is shown in the following table:—

	Age 35 years ago.	Age at present.	Estimated average weight 35 years ago.	Estimated average weight at present.
Great Britain ..	3, 4, 5 and 6 years old.	1, 2 and 3 years old.	1,200 lb.	950
United States ..	4, 5 and 6 years old.	2 and 3 years old.	1,100 lb.	950

Dairy Stock.—The improvement in the yields of milk and butter-fat in our dairy cattle is equally striking. Less than thirty years ago yields of from 600 to 800 gallons of milk were considered high. The average yield of milk per cow throughout the British Isles has been estimated at or about 450 gallons. To-day an average yield of 1,000 gallons is by no means uncommon in many herds, and we find that individual animals have given up to 2,000 and 3,000 gallons in one lactation period. This has been brought about by improved breeding, better methods of feeding and management, and by milk recording.

Poultry.—In the case of poultry we have improvements on a similar scale. The average output per hen was estimated as being under 100 eggs not many years ago, now there are numerous poultry farms showing returns of an average of over 150 eggs per bird, and the egg-laying contests held by our Governments and Local Authorities show averages of 180 to 190 eggs per bird.

Baby Beef.—The production and demand for baby beef has been steadily growing since 1918 in the British Isles and in the United States of America.

Mr. Wentworth in a letter to me on December 21, 1927, says:—

'It is difficult also to say just what effect the demand for small joints in America had in directing attention to baby beef production. Originally I believe it was a by-product of the general trend toward a quick turnover in farm finance, but it was unexpectedly intensified by the great changes in demand which occurred during and just after the World War. This demand first expressed itself so effectively that light-weight cows and thin steers brought nearly as much on the market as quality animals. Then the beef cattlemen discovered they could compete quite effectively and still produce quality animals through baby beeves. I should say that at present the demand for small joints is the principal incentive, but originally it was the stimulus towards a quick turnover.

'Our Beef Department estimates that there were about ·5 per cent. of baby beeves in 1900, about 3 per cent. in 1918, 8 to 10 per cent. in 1920, and about 20 per cent. for the current year.'

The Ministry of Agriculture in Northern Ireland in the years 1923–24 carried out a series of experiments (devised by Dr. G. S. Robertson) on the production of baby beef with animals sired by pedigree beef Shorthorns, pedigree Dairy Shorthorns, pedigree Aberdeen Angus and by the ordinary

cross-bred bulls of the country. These animals were reared in the ordinary way followed in Northern Ireland, viz.: for the first six weeks they were fed on whole milk, and for the next four or five months on separated milk with concentrates. During the whole period of their growth they were never allowed to lose their calf flesh. The animals were slaughtered when from twelve to eighteen months old. The results of these experiments clearly proved that when animals were well bred, the progeny of a good pedigree sire, the production of baby beef was an economic success, but when the animals were badly bred it was a complete failure. The ill-bred calf simply grew but would not put on flesh. These experiments have induced many farmers throughout Northern Ireland to convert their calves into baby beef instead of pursuing the ordinary system of producing stores, with the result that now special sales of baby beef are being held annually in Northern Ireland and are largely attended by cross-Channel butchers.

The lesson which these experiments have taught is that unless the breeding stock of the country is improved and graded up to a high standard, the progeny will not mature quickly and will never be suitable for baby beef production. If the demand for small joints of beef continues to grow and becomes permanent, and if we are to hold our own against foreign competition, it can be met only by paying far more attention to the improvement of our stock than we have done in the past or are doing at present, and this will be chiefly through the increased use of good pedigree sires. The strongest argument for the elimination of inferior sires is that there is a growing demand for a higher quality of meat and, therefore, a high standard of breeding and feeding is necessary for further development.

Advantages of Early Maturing Stock.

In addition to meeting the market demand for small joints, early maturity has considerable economic advantages, namely :—

1. It gives a much quicker turnover, and is of material assistance in eliminating intermediate profits. At present in the case of beef three types of producers are frequently engaged in the production of the finished article: the rearer, who sells at the age of nine to fifteen months to the grazier of store cattle, who in turn, after a summer on the grass, sells to the arable farmer for stall feeding.

2. The young animal is the more economical converter of food. The older an animal is, the greater is the amount of food required to produce 1 lb. of live weight gain. Moreover, after a certain weight is reached, 200–240 lb. in the case of the pig, and probably about 800 lb. in the case of the fattening bullock, the daily live weight gain falls. It follows, therefore, that as the demand is for small joints and as the consuming public is paying higher prices for small carcases, it is greatly to the advantage of the stock feeder to finish his animals off at as early an age as possible. In this connection may I express the hope that our Animal Nutrition Research Stations will soon be able to provide the farmer with badly needed data for the several types of farm animals, showing the amount of food required at varying weights to produce 1 lb. of live and dead weight gain. For pigs the information is available. In

the case of beef the classic experiments of Lawes and Gilbert and the more recent investigations by Haecker at Minnesota on beef production are all that the practical stock feeder has to guide him. Both of these investigations apply to the production of heavy mature beef and, although models of their kind, are of questionable value under modern conditions. I have found it impossible to obtain figures showing the daily live weight gains for lambs. Most of the experiments carried out by Agricultural Colleges on the feeding of sheep relate to the full-grown or nearly mature sheep and show daily live weight gains of from only $\frac{1}{4}$ to $\frac{1}{2}$ lb. per head per day. On my own farm I have been producing early lambs from heavy breeds for many years and have made a practice of weighing them every week. My experience is that when early lambs and their dams are forced with green fodder and concentrates from the birth of the lambs until the latter reach a weight of 90 lb., the lambs will gain $\frac{3}{4}$ to 1 lb. per head per day, but that after a weight of 90 lb. has been passed the daily live weight gain decreases.

3. Young animals finished for the butcher realise higher prices per lb. than older and heavier animals correspondingly finished. Early maturing or baby beef realises at least 6*s*. more per cwt. live weight than heavy beef 10 cwt. or over, and early lamb as a rule from 25 to 50 per cent. more than mutton.

It is sometimes argued that if all flesh-producing animals were slaughtered at a much earlier age than at present our live stock population would be reduced. This is not so. Experience in the United States of America, which has already been quoted, shows that as the age of slaughter of the beef cattle on the ranges became less, the number of breeding females increased and also the number of cattle slaughtered per annum. The same trend of events would be manifest in this country, indeed it is beginning, and a rapid extension is badly needed.

The marketing of our stock at an early age enables the farmer to turn out a finished article at a reduced cost of production for which a higher price is obtainable and provides him with the only effective means of holding his own against the best imported beef and mutton.

State Aid to the Live Stock Industry.

Let us now see what is being done in Great Britain, Northern Ireland and the Irish Free State towards the improvement of live stock by financial assistance from the State.

Until quite recently all efforts to improve the live stock of the Empire were left entirely to private individuals—the breeders of pedigree stock—and this small band of enthusiastic workers have left behind them a notable monument to their skill and unremitting labours in the formation of breeds and in the improvement which they effected in the type and quality of pure bred stock.

It was only at a comparatively recent date that the British Government considered the agricultural industry to be of sufficient importance to justify the State in making some financial provision for its improvement and development.

The first Parliamentary grant for the special purpose of live stock improvement was voted in 1885. This grant was given to Ireland to be

administered under the auspices of the Royal Dublin Society who adopted the method of subsidising pedigree sires, and thus Ireland was the pioneer country in the British Empire to undertake live stock improvement with the help of a State grant.

Since 1914, Parliamentary grants for the improvement of live stock have been made to the Ministry of Agriculture and Fisheries and to the Board of Agriculture for Scotland, and each of these Departments put into operation schemes somewhat similar to those in Ireland.

The live stock schemes originally devised by the Royal Dublin Society were continued and developed by the Irish Department of Agriculture which was established in 1900, and on the formation in 1922 of separate Parliaments for Northern Ireland and for the Irish Free State still further extensions of the schemes were made by the Agricultural Departments of these two Governments.

The latest published figures for each part of the United Kingdom and for the Irish Free State show the total number of breeding stock, the total number of bulls and the number of these sires subsidised to be as follows :—

	No. of Breeding Stock (cows and in-calf heifers).	Bulls.	Subsidised Bulls.
England and Wales ..	2,790,703	88,405	1,287
Scotland	460,317	17,578	937
Irish Free State	1,332,591	23,275	2,205
Northern Ireland.. ..	270,283	4,662	623

From these figures it will be seen that the proportion of subsidised to non-subsidised bulls and the number of breeding stock per subsidised bull vary very considerably in the several parts of the British Isles.

	Subsidised.		Non-subsidised.	No. of Cows per subsidised Bull.
England and Wales ..	1	to	69	2,168
Scotland	1	to	19	491
Irish Free State	1	to	11	604
Northern Ireland.. ..	1	to	7	434

Turning for a moment to the Dominions—

In Canada the improvement of live stock is developed chiefly by two methods :—

1. The Live Stock Branch of the Department of Agriculture of the Dominion Government purchases and loans out pure bred bulls to specially organised associations in newly settled districts and in backward sections in the older Provinces. This system was commenced in 1913 and 4,692 bulls had been placed out on loan up to 1926, an average of 361 bulls per annum. By this means the value of pedigree sires has been demonstrated and farmers have been induced to purchase pure bred sires for their own use.

2. By grading beef cattle, sheep and lambs according to age, quality and weight when they are put on the market and by demonstrations and

propaganda, attention is drawn to superior beef and mutton. In this way a growing demand from the consumer for more tender and juicy joints has been created. This plan has directly assisted breeders to improve their stock as considerably higher prices can now be obtained for prime beef, mutton or lamb than for coarse joints. The Canadian Government is paying special attention to this side of marketing with remarkably successful results. The home consumption of meat and eggs per head has gone up considerably since this sytem of grading was commenced. Thus, in 1916 the consumption of eggs per head was sixteen dozen. In 1927 it had increased to twenty-eight dozen and all exports had ceased.

Australia (Queensland) in 1925 adopted a scheme by means of which the Department of Agriculture made available to the approved purchaser of a pedigree bull a subsidy of 50 per cent. of the cost price, provided the subsidy did not exceed £50.

In South Africa a scheme for the distribution of pedigree bulls to farmers in the Transvaal through breed societies came into operation in 1924. These animals are sold to selected applicants at reduced prices. Several of the Agricultural Schools throughout this Dominion have stud farms, and young sires raised on these farms are sold and placed out under the Department's bull distribution scheme.

I have already mentioned that in Ireland the first State-aided live stock breeding schemes were started over forty years ago, and although the value of these schemes was clearly shown in the great improvement in the stock of the country both in quality and in the increased prices obtained, the results achieved were not anything like what they would have been if the widespread use of animals totally unsuitable for breeding purposes had been prohibited. The scrub bull not only inflicted serious damage on the owners of cows but lowered the reputation and value of Irish live stock and to a large extent neutralised the good effect of the live stock schemes.

These were the chief reasons which induced the Governments of Northern Ireland in 1922 and of the Irish Free State in 1925 to introduce legislation providing that bulls below a certain standard of merit should not be used for breeding purposes and that all suitable bulls should be licensed. By subsidising pedigree sires we have the means of improving and grading up our stock and by permitting the use of none but licensed sires we get rid of the inferior animals and prevent them from doing harm. This ensures that the improvement is continuous and that much quicker results are produced.

In England and Wales there is only one premium bull to every sixty-nine non-premium bulls and there are 2,168 cows to each premium sire, whereas in Northern Ireland, where more than half the number of bulls are pedigree animals, there is one premium bull to every seven non-premium bulls and 434 cows to each premium sire. Yet after forty years' experience of the premium scheme we have found it absolutely necessary to bring in a licensing system to supplement the former owing to the progress of improvement being so comparatively slow.

Great Britain has the reputation of having the finest pedigree stock in the world, and yet probably nowhere else in the British Empire is improvement in the cross-bred cattle more urgently needed. It is a

strange anomaly that our pure-bred stock are exported to all parts of the Empire and to foreign countries for the improvement of the native stock, while at home our own cross-bred stock are in comparison so inferior to the pure-bred stock.

In Canada, United States, Australia and South Africa the elimination of the scrub bull has received attention, and these countries in recent years have instituted with considerable success campaigns against the use of inferior sires. Western Australia introduced legislation which came into operation in 1924 to enable their agricultural department to get rid of scrub bulls.

Bull Licensing Act and its Administration.

The main features of the Live Stock Breeding Act of 1922, which came into operation throughout Northern Ireland in January 1924, are :—

1. The licensing of bulls of the prescribed age, and the prohibition, enforced by penalties, of the use of unlicensed bulls.
2. The granting, as a temporary measure, of permits to owners who feed bulls for beef.
3. A fee of 5*s.* is charged for a licence for each animal, and the licence remains in force during the lifetime of the animal unless revoked or suspended by the Ministry.
4. All bulls passed as up to licensing standard are tattooed on the ear with a letter and a number.
5. An owner can appeal against the decision to reject a bull for a licence. When such an appeal is lodged the animal is inspected by an appeal judge who is a breeder of cattle, and not an official of the Ministry. To prevent frivolous appeals a fee of £2 2*s.* must be lodged. This fee is returned to the owner if the appeal is successful.
6. Inspections are held twice each year—in February and September.

Appeals.—Since the Act came into operation there have been eighty appeals against the decision to reject bulls for licences. In these cases the bulls were re-examined as provided in the Act, with the result that twenty-five of the bulls were licensed and fifty-five finally rejected.

Rejections.—The percentage of bulls rejected for licences at each inspection since the Act came into force was as follows :—

September 1923		5·7 per cent.
February 1924	15·4	=17·2 per cent.
September 1924	22·5	
February 1925	23·0	=23 per cent.
September 1925	23·0	
February 1926	36·3	=33·5 per cent.
September 1926	20·6	
February 1927	21·4	=20·5 per cent.
September 1927	17·6	

The point of interest in this table is that in the last year the rejections were less, although the standard for selection was raised. This is due entirely to better-class bulls having been produced.

In its administration of the Act Northern Ireland has advisedly adopted a cautious and lenient policy. Beginning with the rejection of only really low-grade bulls, the Ministry at each subsequent half-yearly inspection has gradually raised the qualifying standard of bulls eligible for licences. By this method the small farmer is being educated to the advantage of using good-class bulls, and consequently it is expected that in the near future only those bulls which are up to the standard now required for premiums will be licensed.

Inspections.—Inspections are carried out twice each year, in February and September, and in order to convenience farmers and simplify procedure, the Six County area of Northern Ireland is mapped out into a number of districts in each of which numerous centres are fixed by the Ministry for the inspection of bulls. In selecting centres the Ministry endeavours to ensure that owners will not have to bring their animals a greater distance than three miles. In addition, inspections of bulls are carried out at the annual spring bull sales held throughout the Six County area. The officers appointed as inspectors are permanent officials of the Ministry, and are entirely employed in connection with the Ministry's live-stock schemes. The method devised of having local centres instead of inspecting animals on owners' premises was adopted in order to reduce the cost of inspection. It also enabled the inspectors to compare the bulls shown and to keep a much more uniform standard than would be possible in a house-to-house inspection. At first it was frequently asserted that the administration of such an Act would be extremely expensive, and would entail the employment of an army of officials, but this has proved to be quite a misapprehension. The Ministry did not increase its staff, but carried out the inspections with three of its regular live stock officers, who devote about one month each year to this particular work. The fees received cover the cost of inspection.

Assistance to Small Farmers.

It is common knowledge that the quality of our herds varies greatly from district to district, and it is obvious that the operation of a Live Stock Breeding Act, such as has been outlined, will bear much more heavily on the poorer districts where the cattle are inferior. It is in such districts that the largest percentage of bulls is rejected, and if the real objects of the Act are to be achieved the State must under such circumstances be prepared to give practical assistance. In the poorer districts in Northern Ireland, where a large percentage of bulls was rejected for licence, the Ministry, through the county committees of agriculture, purchased and sold pedigree bulls to approved applicants on reduced terms. These are in addition to those animals which were placed out under the ordinary premium scheme, where premiums of the value of from £15 to £20 per annum are awarded.

Animals under the reduced price scheme are sold to selected applicants at one-third the original cost. The applicant pays the one-third in three equal instalments, the first when he gets the bull, the second in the following October, and the third in October of the following year. If the owner keeps the animal in good condition and complies with the regulations of

the scheme, he receives as a premium each year an amount equal to the instalment he pays, so that in the end the bull costs him nothing. To take an example, if a bull costs say £15, it is sold for £15 to the applicant, who pays £5 when he gets possession of the animal in February or March. The following October he pays the second instalment of £5 and the third is paid in October the next year.

The owner receives a premium of £5 in October of the year in which he purchases the bull, and a second and third premium, each of the value of £5, in October of the two following years.

Loans are also given for the purchase of premium bulls.

Assistance to Breeders of Pedigree Stock.

One of the most noteworthy features of the Bull Licensing Act is its indirect effect in increasing the demand for pure-bred sires. The supply must be forthcoming if progress is to continue and confidence is to be promoted. In countries such as England and Scotland, where large pedigree herds are maintained and pedigree stock exported, an increased demand for pure-bred sires can be quickly met. Pedigree breeders in Northern Ireland are as a general rule small farmers with very limited herds, and, however willing, they are financially incapable of competing for the high-priced pedigree sires.

In order to overcome this difficulty a scheme has been put into operation whereby if three or four breeders of pedigree stock who have between them sufficient cows to mate with one bull will co-operate in the purchase of a high-class pedigree bull, the Ministry will pay two-thirds of the cost up to £500, and will give a loan for two-thirds of the balance to be paid off in three or more instalments. By this means encouragement is given to small breeders of pedigree stock who otherwise could not afford to purchase high-class sires.

Fears not Realised.

Breeders of pedigree stock were apprehensive that if a licensing scheme were introduced stock sires not up to the standard in appearance would be rejected and no attention would be paid to the animal's pedigree. Since the Act came into operation no pedigree stock bull has been rejected for a licence. A breeder may have a pedigree stock bull of plain shape, and perhaps not up to licensing standard, but as this sire may represent the best obtainable where the choice was narrowed by such considerations as a particular pedigree or a special line of blood related to the breeder's own herd, the bull is licensed. If, however, the young bulls produced by this sire are not up to licensing standard, they will be rejected, and the owner will at once get rid of the stock bull, as no breeder of pedigree stock will keep a stock bull which is leaving unremunerative progeny.

The fears expressed at one time that the Act would encroach unduly on the farmers' liberty of action have likewise proved groundless. In actual practice the measure interferes only with the farmer who, by keeping an inferior sire, would counteract the efforts of the State and of local authorities to improve the live stock of the country.

Is Further State Aid Required?

Would it be advisable for the State to devote larger funds than are granted at present to the improvement of live stock?

My opinion is that, as the money which has already been applied to this purpose has proved so reproductive, and as the live stock breeding industry is so important to the whole community, it is questionable if funds expended in any other way could produce anything like the same returns.

Here I may quote from evidence given in January 1923 by Mr. T. P. Gill, who for over twenty years was Permanent Secretary of the Department of Agriculture, Dublin. He stated before the Commission on Agriculture, appointed by the Irish Free State, that—

'By the infusion of pure bred blood and better methods of keeping, feeding and management, producing an animal which matures more quickly, fattens more cheaply and yields more beef and milk, the intrinsic value independent of price fluctuations of Irish cattle has been increased since the department started in 1900 by about £5 per head. This is based on the estimates of the British Salemasters who handle this import as well as of the most experienced Irish cattle traders. On the number of cattle exported last year, counting the exports only, this would mean an increased annual income of approximately £5,000,000 for an expenditure of £20,000, or a return of 250-fold.'

If we calculate that the increased value was only £3 per head, it means £3,000,000 per annum, or a return of 150-fold.

Some will think, perhaps, that I have laid too much stress on the importance of the pedigree sire in the improvement of stock, but the improvement which has taken place in the stock of the Argentine Republic gives us food for thought. In 1848 the first Shorthorn bull was imported into that country. At that time only native breeds existed, animals which from our standard were of very inferior quality and extremely slow-growing. The Rural Society founded in 1875 was the chief agency in bringing about improvement in the live stock of the Argentine chiefly through the importation of pedigree sires and through the shows of live stock held by the Society.

In 1895 native cattle constituted 50 per cent. of the total in the province of Buenos Aires. In 1914 this had declined to 3·5 per cent. The cross-breds and half-breds increased during this period of twenty years from 49·2 per cent. to 93·9 per cent., and the pure-bred or pedigree cattle from 0·6 per cent. to 2·5 per cent.

Similar progress in the case of sheep has been recorded. In 1895 native breeds constituted 16·5 per cent. of the total; in 1914 they had fallen to 2·3 per cent. The cross-breds increased during this period from 83 per cent. to 95·6 per cent., and the pure-breds from 0·5 per cent. to 2·1 per cent.

In the other provinces an equally noticeable improvement has been effected.

Between 1895 and 1922, 41,519 pedigree bulls were exported from the British Isles to the Argentine.

To-day the best quality Argentine chilled beef ranks next to the best

home-produced, and in Smithfield Market it commands prices higher than some of our own home-produced and considerably higher prices than any other imported beef.

The following figures from the *Statist* show the prices of home and Argentine beef for the year before the war, for 1926 and for 1927 :—

Class of Beef.	Prices per stone of 8 lb.		
	January 30, 1914.	December 2, 1926.	December 3, 1927.
Argentine chilled hind-quarters	3s. 8d. to 3s. 10d.	3s. 10d. to 4s. 4d.	4s. 8d. to 5s.
Scottish sides	4s. 6d. to 5s.	6s. 6d. to 7s. 4d.	6s. 4d. to 7s.
English sides	4s. 2d. to 5s. 1d.	4s. 8d. to 5s. 6d.	4s. to 4s. 10d.

English sides, it will be observed, have actually fallen in price since 1914, whilst Argentine chilled beef has risen. The substantial difference in favour of English beef over Argentine chilled beef which existed in 1914 has disappeared. The two principal factors in this revolutionary change are the use of pedigree sires and marketing methods. Surely no stronger argument could be put forward for the urgent necessity for the improvement of the cross-bred cattle of the British Isles.

Need for Extended Research.

Although I consider that the pedigree sire is the best foundation for the improvement of live stock it is by no means the only way by which improvement can be brought about. The changes and improvements already mentioned are largely the results of the ability and judgment of the breeder himself, but latterly he has been assisted considerably by the agricultural scientist, chiefly along four distinct lines of research and experiment :

1. Animal Nutrition.
2. Animal Diseases.
3. Animal Breeding.
4. Marketing.

Animal Nutrition.—Animal nutrition is of the greatest importance from three points of view—

(*a*) I am sure that most stock owners will agree that the greatest mortality in live stock is due either directly or indirectly to imperfect nutrition and not to disease—probably seven out of every ten deaths occurring on farms in the British Isles (excluding those caused by accidents) are due to imperfect nutrition.

(*b*) Owing to early maturity and forcing young animals forward to an age when they are ready to be killed, a much more thorough knowledge of foods and the science of feeding is necessary than under the old system. In the case of cows with high milk yields and of poultry where high egg records are being produced such knowledge is specially required.

(*c*) The practical farmer as a rule has little or no knowledge of how to form well-balanced rations ; indeed he has a very slight knowledge of the

composition of foods and of their physiological action. How could it be otherwise when we consider that it is only of recent date that attention has been given by agricultural scientists to the necessity for balanced rations in feeding different kinds of stock and how little even they know about the digestibility of foods, the proper balance of a ration and the action of minerals in relation to health and disease resistance.

In 1890 the British Government gave Local Authorities (County Councils) in Great Britain grants to be used either for reducing rates or for agricultural and technical instruction purposes. Many of the County Councils from the beginning utilised those funds entirely in developing agricultural and technical instruction schemes and in later years all the County Councils expended these grants in this way. From 1890 until a few years ago practically all the funds made available to Local Authorities for the development of agriculture were applied to agricultural education, experimental and research work chiefly in connexion with soils, manures and crops, comparatively small amounts being devoted to research and experimental work on live stock problems. Attention has recently been drawn to this fact by Mr. J. R. Campbell, who in his report (November 1927) on Agricultural Education in Scotland states :

'Owing no doubt to the greater cost and difficulty in carrying out experiments in the rearing and feeding of stock, this side of farming—though not wholly neglected—has received comparatively little attention in the way of experiments outside the College farms. It is to manuring and cropping that lectures and field work have been chiefly directed.'

While I realise the great advantage to be gained by the application of science to soil, fertiliser and crop problems, the chief factor in the British Isles is live stock, and it has been to a great extent neglected. It is, as I have shown, the chief source of our farmers' income—the hub of the wheel—and, so long as the production of live stock is an economic success and crops are utilised chiefly by converting them into live stock products, more attention should be given to research on live stock problems than to the experimental side of soils, manures and crops.

This position is, however, being rectified, and we have now research stations engaged in animal nutrition work at Aberdeen, Cambridge, Belfast and Dublin, but the funds available are quite inadequate if this work is to be developed on broad lines and is to be of practical assistance to the stock breeder in his efforts to overcome many of his difficulties and losses.

Animal Diseases.—I am sure that no one will question the need for extended research into the diseases of our farm animals or the necessity for protecting our live stock industry against epidemics which annually threaten it so seriously. In connexion with the latter I may refer to the outbreaks of foot-and-mouth disease in Great Britain which have been almost continuous since 1919, and which have been the cause of the loss of so many stock through slaughter. During the last nine years, 1919–1928, no fewer than 162,214 cattle, 114,679 sheep, 71,536 pigs and 256 goats have been slaughtered, and the compensation paid to farmers amounted to £5,314,000. This does not by any means cover the full value of pedigree stock, as only commercial prices are paid in compensation, nor does it include the administrative expenses incurred in stamping out each

outbreak of this disease. Moreover, when whole herds of pedigree stock are slaughtered, it means in many instances the destruction of the life work of breeders—work which can never be replaced—and for this loss no sum could ever compensate the breeders or the State.

Here is a field of research which would justify the State in devoting large sums in order to employ the most skilled scientists obtainable to ascertain a means of prevention. When we consider the enormous cost to the nation and the constant danger of losing our best pedigree herds, as well as the possibility of losing our trade in pedigree stock with other countries, the justification for further and immediate research in this direction is apparent.

Considerable loss to our agriculturists is caused by many other animal diseases regarding the prevention of which very little is known. Those which occur to me as being some of the most important are tuberculosis, abortion, infertility or sterility. The first named not only causes loss through the death of animals but is a constant source of danger to human beings through the consumption of milk from tubercular cows. The latter two diseases are widespread in many areas and affect seriously the production of stock. These are only a few of the many animal diseases into which research is required and for which adequate funds are urgently needed.

Animal Breeding.—One of the greatest problems which breeders have to face in the management of their studs, herds and flocks, is the selection of sires. Both amateur breeders and old experienced breeders have the same difficulty, viz. how to select a prepotent sire. The only way in which breeders can determine this at present is by the offspring. This means a delay of two years in the case of beef cattle and from three to four years in the case of dairy cattle. If, at the end of that time, the sire proves unsuitable, the owner may have from two to four crops of calves inferior to their parents and, therefore, of no use in improving the herd, and such animals have to be sold at an unremunerative price. The owner suffers a considerable loss in time as well as money and runs the risk of ruining his herd if he retains animals of this blood.

Owners of small flocks or herds cannot afford to keep more than one high-priced sire, and therefore are handicapped much more than those who own large herds or flocks. The latter can afford to keep a number of sires on trial, mating each with only a few females until each sire is proved, instead of risking all the herd with one unproved sire, as has to be done in most cases by small breeders. It may be of interest to mention that in Scotland most of the herds of pedigree cattle are in the possession of tenant farmers, many of whom have only small farms. In Northern Ireland there are 682 pedigree herds and the majority of the owners have farms under fifty acres. These breeders could not afford to keep more than one sire or to pay a very high price for a pedigree sire.

Money may enable the breeder to procure a high-class sire of a fashionable pedigree, but this is no guarantee that the sire will prove to be a good stud animal, as it has frequently happened that the progeny of high-priced animals turn out unsuitable and are unsaleable, except at a low price. Pedigree is a guide, if used properly from a genealogical point of view, to trace the family and the line of blood. Experience and

judgment also assist the breeder in his selection, but even the most experienced breeders and keenest judges often purchase animals which turn out quite unsuitable as sires. The individual merits or records of the parents are exceedingly important factors, but by no means can you rely on these to enable you to select a suitable sire. Luck or chance, up to the present, seems to outweigh all the other factors combined in the selection of a sire.

Another problem is how to induce breeders of commercial stock and even breeders of pure-bred dairy stock to keep their bulls until such time as the value of their progeny can be determined, and then to retain, so long as they will produce stock, those sires which are proved to be suitable. This question is of the greatest importance in dairy herds, where frequently the bull is dead when his daughters are proved to be good yielders of milk and butter-fat. Well-bred bulls should be retained until the daughters have demonstrated their sire's true value, and, by the exclusive use of such pure-bred bulls, a real advance would be made in the breeding of dairy stock.

Many pedigree herds and flocks have made names or high reputations simply as the result of having one prepotent sire, and when that sire died these herds for years afterwards lost their reputation for high-class stock. If the animal geneticists could show us how to diagnose a prepotent sire or how to breed animals with this hereditary trait and make breeding more of a certainty and less of a gamble, it would encourage and give a stimulus to the breeding of high-class animals, which would reach much further than any form of State subsidy given directly to breeders of pedigree stock, and would be worth millions in money to stock breeders throughout the world.

Marketing and Grading.

The marketing and grading of animals and their products is a very wide subject, and one which could only be dealt with effectively by devoting a special paper to it alone. I will, however, touch briefly on one or two points.

In Great Britain until recently practically no attention has been paid to the grading for marketing purposes of animals or animal products, and those measures which have been taken are entirely voluntary. In Ireland voluntary schemes have been in operation since 1900, but with such small success that compulsory measures for the grading of eggs were put into operation in 1924 by legislation in Northern Ireland, and similar legislation for the grading of eggs and dairy products was adopted by the Irish Free State. It is anticipated that, in the near future, further legislation will be passed in Ireland for the grading of pigs and other products.

In Canada voluntary measures were tried for many years, but both the Government and the farmers in that country were ultimately convinced of the necessity for compulsory powers, with the result that laws of the most drastic character are now in force in that Dominion insisting upon the grading of all animal products, both for export and home consumption.

New Zealand, Australia, South Africa and many foreign countries also have passed similar legislation for certain products.

These countries are all competitors of ours, and by means of legislation

they are enabled to put upon our markets animal products so uniform in quality, so even in weight, &c., that they have obtained a reputation for a reliable standard article which has won the confidence of the public to such an extent that consumers frequently insist upon having certain products from these countries in preference to similar home-produced articles. I refer in particular to New Zealand lamb, New Zealand butter, Canadian cheese, Argentine beef, Danish eggs, &c.

In the case of all chilled and frozen beef and mutton imported into Great Britain, the carcases are so graded according to quality and weight that a retailer can order his precise requirements from a wholesaler by the mere mention of brand, quality and weight, and so regular is the grading that a customer can depend on obtaining what he requires without having to examine the article.

In the Argentine beef is graded into three qualities which enables them to supply three different markets. The Australian and New Zealand mutton and lamb are also divided into three grades, and latterly, owing to the demand for small joints, the second-quality lambs of smaller weights frequently command a higher price in our market than the heavier first quality.

By not marketing our home produce properly, that is by not grading, we are not only receiving inferior prices, but we are losing our position in our home markets and are permitting imported produce to secure a position which it could never attain if only our home products were of high quality, and were placed on the market in a more reliable and uniform condition as regards quality, weight, appearance, &c. For fresh home-produced supplies of first quality and of the proper weight the demand in this country is unlimited, and such supplies will always command prices considerably in excess of those for imported animal products.

While personally I am opposed to placing any unnecessary restriction on the liberty of the subject, I must say that, judging from my experience of the past twenty-eight years in Ireland, and noting that the Dominions, as well as many foreign countries, have had to resort to legislation, I fear that it will be found difficult, if not impossible, to secure reform in the grading and marketing of United Kingdom animal products through voluntary effort alone.

Conclusion.

To sum up, I should like to emphasise the supreme importance of the live stock side of our agricultural industry, the immense scope for development which exists, and the exceedingly rapid strides which can be made in its development by the application of our present knowledge along properly organised lines. It is my opinion that we can, if we choose, do for stock in the relatively short period of ten to fifteen years what has been accomplished for crops from 1840 to the present time. Unless we bestir ourselves and organise our efforts we shall find our home markets for stock and stock products in the hands of our competitors, who already, by purchasing the best of our pedigree sires, are placing on our markets products which are superior to the great bulk of our home-produced supplies.

The pressing necessity at the moment is for improvement in our

commercial cattle—the great disparity between them and our pedigree stock is little short of tragic. I make no apology for submitting to you that the means towards this end are:

(1) The increased use of pedigree sires, and in this direction the State can with great advantage to itself provide a powerful stimulus by the rapid extension of the premium scheme;

(2) The elimination of the scrub bull, which, to my mind, with human nature as it is, will only be accomplished in an effective manner by legislative means.

It must not be forgotten, however, that as progress is made in grading up our stock by breeding methods, it is imperative that there should be corresponding developments in our knowledge of nutrition, disease resistance and elimination, and in animal genetics. Research in these branches of agricultural science has in the past been starved. The funds devoted to such work are quite inadequate when viewed in the light of the importance of the live stock industry, which in England and Wales alone is worth, approximately, £154,000,000 per annum.

In connexion with this work may I stress the necessity for such research to apply itself more directly than at present is the case to the solution of practical problems. No one realises more than I do the need for fundamental research, or, as it is now called, long-range research, but the agricultural scientist should be, as his designation implies, essentially an applied worker. I venture to think that in setting themselves some of the problems which I have sketched they will meet with sufficient really fundamental problems to keep them employed for many years to come.

Finally, I would reiterate the necessity for a comprehensive reorganisation of our methods of marketing stock and stock products. If it can be accomplished on a voluntary basis so much the better, but I am convinced that compulsory legislation will eventually be necessary. Much valuable time will be saved by facing this position at once. There is a future, and a bright future, for the live stock industry, but only if we are prepared to tackle the problems which it presents in a live and organised manner. I have endeavoured in this address to summarise my own experience of over thirty years of intimate association with animal husbandry, and to put before you for consideration how, as the result of that experience, I conceive this great national industry can best be developed.

REPORTS ON THE STATE OF SCIENCE,
ETC.

Seismological Investigations.—*Thirty-third* Report of Committee* (Prof. H. H. TURNER, *Chairman*; Mr. J. J. SHAW, *Secretary*; Mr. C. VERNON BOYS, Dr. J. E. CROMBIE, Dr. C. DAVISON, Sir F. W. DYSON, Sir R. T. GLAZEBROOK, Dr. HAROLD JEFFREYS, Prof. H. LAMB, Sir J. LARMOR, Prof. A. E. H. LOVE, Prof. H. M. MACDONALD, Dr. A. CRICHTON MITCHELL, Mr. R. D. OLDHAM, Prof. H. C. PLUMMER, Rev. J. P. ROWLAND, S.J., Prof. R. A. SAMPSON, Sir A. SCHUSTER, Sir NAPIER SHAW, Sir G. T. WALKER, *and* Mr. F. J. W. WHIPPLE). [*Drawn up by the Chairman except where otherwise mentioned.*]

General.

WE regret to record the death of Mr. W. E. Plummer, Director of the Bidston Observatory, who was a member of this Committee from 1900 until his resignation owing to failing health last year. He set up at Bidston in 1914 the very earliest seismograph of the Milne-Shaw pattern, replacing a Milne machine which had been set up in 1901.

Dr. H. Jeffreys writes :—Prof. Emil Wiechert, Director of the Geophysical Institute of Göttingen, died on 1928 March 19, at the age of 66. He was the first to investigate the figure of the Earth on the hypothesis of a rocky shell and a metallic core ; he initiated the great Göttingen series of papers, "Ueber Erdbebenwellen" ; and he was the inventor of one of the best known seismographs.

The seismograph basement presented to the University of Oxford by Dr. J. E. Crombie has now been completed at the University Observatory, and the two Milne-Shaw seismographs will shortly be transferred to it from the basement of the Clarendon Laboratory, which has been courteously lent by Prof. Lindemann and his predecessor since October 1918. The first instrument (E.W.) was set up there by Mr. J. J. Shaw just in time to catch the big Porto Rico earthquake (1918 Oct. 11d. 14h. 14m. 25s. epicentre 18·5° N., 67·5° W.).

The salary of Mr. J. S. Hughes has again been provided, half by Dr. Crombie and half by the University ; and it is hoped that this arrangement may be continued at least until the next meeting of the Int. Geod. and Geoph. Union in 1930.

Helpful telegrams have been received, on the occasion of important earthquakes, from Fordham, Helwan, Hyderabad and Perth (W. Australia). Oddly enough, what was perhaps the biggest shock of the year—the great Mexican earthquake (Oaxaca) of 1928 June 17d. 3h. 19m. 13s.—brought scarcely any telegrams at all ; perhaps because it was presumed that the usual information through the Press would suffice. A large area (extending over nine States) was shaken, but the damage done was less than in other similar cases. Possibly the focus was deep-seated.

The earthquakes in Bulgaria and at Corinth in April last were less intense, but caused much damage and naturally attracted much attention. A leader in *The Times* of April 24 contains the following sentences :—

Yesterday came the news of the destruction of Corinth. In 1858 the city of Old Corinth, which had survived the sack by Mummius—who deservedly became the type of the armed Philistine—and the ravages of Goths, Normans and Turks, received its *coup de grâce* from the angry earth. . . . New Corinth had low houses and wide streets. . . . On Sunday their turn came after seventy quiet years. Under the impact of a long series of shocks house after house went down till only a few new buildings were left standing.

An earthquake on 1928 Jan. 6d. 19h. 31m. 40s. epicentre 0·2° N., 36·2° E., was noteworthy from the fact that two Milne-Shaw pendulums had recently been set up at Entebbe (4·6° from the epicentre) by the officers of the Geological Survey of Uganda. The instruments were thrown out of action by the violence of the shock, but good readings of P were available.

* The previous report (1927) was incorrectly numbered: it should have been given as the thirty-second.

The value of the Indian and Perth telegrams was most clearly demonstrated on the occasion of the shocks under the Indian Ocean in March last. The epicentre may be estimated provisionally at 1·0° S., 91·0° E., more than 90° from European stations.

The illness of Mr. J. J. Shaw required his absence from England for a much longer term than was at first expected; but happily he was able to return to West Bromwich in June and to resume his devoted seismological work.

Miss E. F. Bellamy, owing to the necessity for a serious operation, was absent from Oxford for a number of months, but has been back at work again since May.

International.

The *International Scientific Summary* has been continued as below, though it was feared that, owing to the failure of funds, the printing could not at present be carried beyond the end of 1924. A timely grant of £150 from the Royal Society has, however, cleared off the debt incurred, and we can go forward once more. Altogether the Royal Society has now contributed £375 towards this printing, which could not be carried on by means of the international funds provided owing to the fall in the value of the franc. It is hoped that the new Statutes to be made in 1931 may restore the resources of the Int. Geod. & Geoph. Union to their original magnitude.

There was a successful meeting of this Union at Prague (1927 September 1–8). We heard (in the Seismological Section) a very interesting account from Prof. Imamura of the changes in level which precede earthquakes, and suggest some hopes of anticipating them. M. Nikiforov of Leningrad attended as a visitor (since the U.S.S.R. has not yet joined the Union) and showed a map of numerous actual and proposed stations extending from Leningrad to Vladivostock. It was also pleasant to have for the first time a representative from Denmark. Stations are now at work, not only at Copenhagen (55° 41′ N., 12° 27′ E.), equipped with Wiechert, Galitzin, Milne-Shaw and American torsion seismometers, but at Ivigtut in S.W. Greenland (61° 12′ N., 48° 11′ W.); and a third will be erected at Scoresby-Sund on the east coast of Greenland at 70° 29′ N., 21° 57′ W.

A large Committee was appointed to deal with the question of revising the tables of P, S, and other waves. The former officers were re-elected (President, H. H. Turner; Vice-Presidents, E. Oddone, H. Fielding Reid, J. Galbis; Secretary, E. Rothé) and Prof. Salamon of Prague was also elected a Vice-President. After the formal meeting there were two very pleasant excursions, one to the western and the other to the eastern parts of Czecho-Slovakia.

Instrumental.

Mr. J. J. Shaw will make his Instrumental Report at a later date.

The Superintendent of Kew Observatory writes on July 21:—

It is a well-known difficulty in maintaining a seismograph for recording the vertical component of the earth's motion that the elasticity of a suspension spring is liable to considerable changes when temperature is varying. With the Galitzin vertical pendulum a change of 1° C. in the temperature of the apparatus was sufficient to put the instrument out of action. At Strasbourg a spring made of elinvar, an alloy with a low-temperature coefficient for elasticity, has been in use for some time. We have been able to obtain, from the Aciéries d'Imphy, a spring made to the specification drawn up by Mlle Dammann for the Strasbourg installation. After preliminary tests at the National Physical Laboratory the spring was taken into use on May 22, 1928. The spring is found to yield continually under the load, but the effect of such temperature changes as occur from day to day in the seismograph room is almost eliminated.

Arrangements have been made for the transmission from India through the Air Ministry of coded messages giving details of important earthquakes recorded at Bombay. When a report has been received from Bombay it is broadcast with the synoptic weather report of the Meteorological Office. The additional information has proved useful in locating earthquakes such as that which occurred in the Indian Ocean on March 9.

Bulletins and Tables.

The *International Seismological Summary* up to the end of 1924 has been printed and distributed, and the three months 1925 January–March are in the printer's hands. From the *Summary* for the seven years 1918–1924 a simple list of epicentres and times has been prepared which the British Association Council have agreed to publish. The *Summary* itself reaches a rather limited public of those actively engaged in seismological observation ; it is hoped that this list of epicentres and times may reach and interest a wider public, including geographers and geologists. It seems probable that seven years' systematic record of this degree of accuracy, now for the first time available, should provide valuable material for systematic discussion. One or two points may be mentioned by way of illustration :—

(*a*) There is not a single day during the whole seven years on which no earthquake was recorded, though there are one or two cases when a shock was recorded at one observatory only, and a good many days when shocks were recorded by two observatories only.

(*b*) The following are the monthly counts of epicentres determined :—

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N	D.
1918 . . .	24	37	25	27	23	33	25	37	52	31	26	32
1919 . . .	18	17	23	18	31	22	44	38	54	33	13	12
1920 . . .	24	33	17	14	33	35	25	17	57	24	21	24
1921 . . .	22	15	24	17	33	20	19	16	27	26	23	16
1922 . . .	22	21	19	32	26	31	23	33	32	17	22	32
1923 . . .	20	33	27	23	40	37	52	46	139	45	49	31
1924 . . .	35	23	47	37	46	24	43	32	83	30	34	37
Mean . . .	24	26	26	24	33	29	33	31	63	29	27	26

It will be seen that there is a sudden maximum in September. The effect of September 1923 is no doubt exaggerated by the numerous aftershocks of the great Tokyo earthquake ; but if we omit 1923 the mean value for September in the six other years is 51, still much in excess of other months. So sudden a maximum cannot be adequately expressed by harmonic analysis unless we use a great number of terms ; but the phases of the first harmonic for the separate years are consistent, viz. : 245°, 202°, 223°, 190°, 178°, 232°, 221°. It was shown in the *Geoph. Supp. to Monthly Notices R.A.S.*, I, 5 (December 1924) that such ' annual ' variations are subject to slow changes which indicate that the period is not accurately one year.

Deep Focus.

The hypothesis that in some cases the focus of an earthquake may lie ·05 or perhaps even ·10 of the earth's radius below the earth's surface has been maintained in these reports and in the *International Seismological Summary* for some half-dozen years, but only recently has any independent testimony been forthcoming in favour of this view, viz. in the (Tokio) *Geophysical Magazine*, Vol. I, No. 4 there is a paper by Mr. K. Wadati on 'Shallow and Deep Earthquakes,' in which he examines specially the earthquake of 1926 July 26d. 18h. 54m. 45s. epicentre 35·4° N., 136·4° E., finding from observations *near the epicentre* a depth of 343 km. = ·054 of the earth's radius. Most of the observations used by Mr. Wadati had not been made accessible to us in Oxford until his paper appeared, but we had observations made at more distant stations, including some near the Antipodes of the epicentre, and on applying the usual treatment to these observations a focal depth of ·055 below normal was readily deduced, in general confirmation of Mr. Wadati's result. Moreover he indicates a number of other cases of deep focus, in all of which, without exception, the usual reductions give results accordant with his, *e.g.* :—

on 1924 April 3d. 2h. 30m. 30s. at 32·0° N., 139·0° E.
1925 April 19d. 15h. 46m. 36s. at 33·0° N., 137·5° E.
1925 May 27d. 2h. 29m. 54s. at 36·5° N., 133·0° E.

In some cases Mr. Wadati has suggested or assigned a deep focus when evidence accessible to us was insufficient. Thus in the *Summary* we printed
1924 June 3d. 2h. 41m. 42s. epicentre 34·0°, 139·5° E. (as on 1924 April 12d.).

	Δ	A_3	P	O–C	S	O–C
	°	°	m. s.	s.	m. s.	
Nagoya . . .	2·4	299	0 46	+ 9	(1 1)	− 5
Osaka . . .	3·4	278	0 54	+ 1	(1 36)	+ 2
Kobe . . .	3·7	282	1 2	+ 4	(1 41)	− 1
Mizusawa . .	5·3	14	1 25	+ 3	2 23	− 2
Ekaterinburg . .	56·2	320	—	—	*e*17 4	−32
Pulkovo . . .	69·8	330	*e*10 55	−21	*i*19 48	−36

No suggestion of deep focus was made at the time on this scanty evidence. But now that Mr. Wadati has made the suggestion, it is easily seen how it will fit in with the negative residuals at Ekaterinburg and Pulkovo. Moreover there is evidence of a similar kind for the previous shock on 1924 April 12d.

A paper has been prepared giving details of the cases (nearly a dozen in all) where independent and accordant results have been reached, and it has been sent to Mr. Wadati for printing in the *Geophysical Magazine* if he so wishes.

CATALOGUE OF EARTHQUAKES
1918—1924

Seismology owes a very great debt to the British Association, which has in this instance, as in many others, taken an infant science under its fostering care. Under the guidance of John Milne a world-wide organisation was started for the use of the seismograph when it was a new instrument, and lists of earthquakes (epicentres and times) were published in the Seismology Reports to the British Association up to the time of Milne's death in 1913. Other organisations were started, especially the splendid Russian network of observatories under Galitzin, and the International Seismological Association which had its headquarters at Strassburg; but the one started by Milne and fostered by the British Association was the only one which survived the war; though the Russian network has now been revivified, and a new international organisation has since 1922 had its headquarters at Strasbourg in place of the one which died with the change of name. Meantime the lists of earthquakes disappeared from the Reports to the British Association, being replaced first of all by lists in the Shide Bulletins which gave not only the epicentres and times as before, but comparisons of the observations with adopted tables. Ultimately the publication of these collated lists was taken over by the Seismology Section of the International Union of Geodesy and Geophysics, and became the International Seismological Summary, of which the annual volumes for seven years (1918–1924) have already been published, each year in four quarterly parts.

2. These Summaries are distributed to all the contributing observatories and to various libraries, but do not reach a very wide non-seismological public. It seems possible that there is such a public (reached, for instance, by the British Association) which might be interested to have, apart from the technical details, a simple list of all earthquakes which occur, with their epicentres and times, such as Milne used to give; though it is easy to give to-day more information than was possible in the early years of instrumental seismology. Accordingly the following catalogue has been prepared from the International Seismological Summary.

3. The first columns give the date of the shock in Greenwich time, the next the latitude (North +, South −) and longitude (East +, West −). Then follows a column showing the number of stations which have given recognisable observations of the shock, thus indicating very roughly which are severe shocks observed at considerable distances, and which are only slight and local. But this indication is subject to a serious systematic error. It is clear that a shock in Europe, for instance, even though slight, may be observed at a number of stations, which cluster round it, while a much severer shock in the Antarctic might escape notice altogether. It would be better to attempt some indication which is independent of the distribution of observing stations; but this would need a special research for which no time has hitherto been available. The work of preparing the Summary has already strained such resources as are available for it. However the Summary itself provides an indication of another kind. Those shocks for which the preliminary wave P has been observed at a distance of at least 80° from the epicentre are undoubtedly in a different class from other earthquakes. The same could not be said of observations of the long waves L, or

the maximum M, which can be observed at great distances for even small shocks; but a recognisable P is another matter; and an asterisk in column 4 marks cases where P has been observed for $\Delta > 80°$. But it must be frankly admitted that no great precision has been attempted in either of these criteria, for they are in any case rough, and to spend time on refinement would be undesirable if not impossible.

4. The column headed 'Former Occasions' is, it is hoped, an addition of some value. It was left an open question for some years whether earthquakes were apt to recur at precisely the same epicentre or merely in proximity to it; and accordingly independent determinations of epicentre were made for successive shocks in the same neighbourhood. But it gradually became apparent that the hypothesis of exact recurrence was often as good as any other, while the convenience of utilising the calculations of Δ and azimuth already made was considerable. Accordingly the habit of using old epicentres became gradually established; and there is this to be said in favour of it, that those who doubt the validity of the implied hypothesis may be glad to have an easy reference to test cases. They may take such a case as that of epicentre 43°·8 N. 11°·2 E. on 1920 Dec. 27d. 16h., and find the reference back to 1920 Nov. 13, which again refers back to 1920 Sept. 16, and that (through a previous shock on the same day) to Sept. 11, and so backwards for a series of thirty-four shocks in all. To test the hypothesis of identity they must of course go to the details in the International Summary; but the present catalogue gives a fair idea of the tendency to recurrence. A list of a dozen good series is given in the Geophysical Supplement to the *Mon. Not. R.A.S.*, vol. ii., No. 1 (p. 70).

5. The column 'Minor Ents.' shows simply the number of observations relegated to the notes, as cases where there is not sufficient material to give an epicentre. Many of them are records at a single station only, unsupported by any independent observation. On some days there are only sporadic observations of this kind, with no serious shock; but *no day* in the seven years is *completely blank*, though on 1921 July 14 there is only one observation. It will be seen that the number of residual observations of this kind is given, on days when there are also several considerable shocks, against the *last* shock for that day.

6. The daggers (†) in column 4 refer to notes collected at the end. Most of these show the cases of anomalous focal depth, expressed in fractions of the earth's radius and counted from the normal focal depth as reference depth. The great majority of shocks come from approximately the same depth below the earth's surface, but whether this normal depth is small or large is still somewhat uncertain. Most seismologists are of opinion that the normal depth is about 50 km. or 30 miles or ·008 radius, and it must be admitted that the evidence in favour of some such figure is very strong. On the other hand there seem to be cases (such as those on 1918 Sept. 7, 8, 12; 1919 May 6; 1922 Feb. 5; 1922 Oct. 17; 1923 Apr. 23) when there is evidence for a focal height of 0·030 or even 0·040 *above normal*, so that the normal depth should be of the order of 0·040. The evidence for these cases is not nearly so strong as that for the deep foci, down to 0·080 *below normal*, but it cannot be ignored; and if the normal depth is small some other explanation must be found for such cases (suggesting heights *above* normal).

7. As regards the cases of depth *below* normal, the case for them has been much strengthened by an entirely independent investigation in Japan by Mr. Wadati, published in the (Tokio) *Geophysical Magazine*, vol. i., No. 4. Mr. Wadati identifies the cases of deep foci in Japan from observations close round the epicentre, and macroseismic information; and his selection is practically identical with that made by the observations at greater distances. For details reference must be made to the International Seismological Summary.

8. Many matters of interest can be obtained from these data, though they cannot be treated here. One illustration may be given. In five years out of the seven September has many more shocks than other months, and in 1921 and 1922, when this pre-eminence is not so marked, it is only second to May in 1921, and ties for first place with April and December in 1922.

H. H. TURNER.

University Observatory, Oxford.
1928 July 23.

CATALOGUE OF EARTHQUAKES, 1918–1924.

An asterisk (*) denotes that there are observations of P beyond Δ=80°; a dagger (†) that there is a note at the end of the catalogue.

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1918 *January*.			
1 15 2 10	+38·0	+ 23·5	4		4
2					13
3					30
4 4 30 5	+10·5	− 91·0	16		
4 4 32 25	+10·5	− 91·0	*21	1918 Jan. 4	
4 15 48 45	− 6·5	+153·5	16	1913 Sept. 3	19
5					14
6					7
7					8
8					6
9					9
10					9
11					10
12 18 38 30	+11·5	+144·0	13	1917 May 9	19
13 8 2 0	−27·0	−172·0	4	1917 May 4	21
14 6 44 40	+43·5	+ 11·8	4		
14 20 2 36	+44·0	− 20·0	11	1917 June 16	13
15 15 29 6	+25·0	+119·5	12†	1915 Jan. 5	6
16 2 33 5	+ 1·5	+110·0	6		
16 7 13 15	+37·4	+ 30·5	25		
16 13 27 25	+19·0	− 80·0	*18	1917 Feb. 20	
16 16 32 6	+38·8	+ 32·9	9		14
17					14
18 10 35 5	+12·0	+ 95·0	11	1917 Jan. 20	10
19					11
20 2 36 45	+39·0	+ 23·0	12	1917 Jan. 13	5
21 19 45 20	− 2·0	+133·0	23		2
22 1 28 44	−15·0	+121·0	2		
22 1 33 58	−15·0	+121·0	5	1918 Jan. 22	3
23					9
24 14 52 36	[illegible] 18·0	[illegible] 172·0	13	1917 June 24	[illegible]

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1918 *February*—contd.			
13 20 25 14	+24·5	+126·5	*23	1917 Aug. 5	
13 22 1 36	+24·5	+126·5	8	1918 Feb. 13	30
14					17
15					9
16					6
17					5
18					13
19 11 3 5	+46·5	+ 13·0	5		
19 16 19 40	−18·0	+167·0	*27	1917 May 14	
19 17 14 35	+27·0	+121·0	6	1917 July 5	17
20					22
21					11
22					12
23 18 2 15	−21·5	−171·5	9		11
24 23 0 16	+11·0	− 62·2	28		7
25 6 3 17	−21·5	−171·5	12	1918 Feb. 23	11
26 10 20 30	−14·0	+150·0	3		12
27 3 12 15	−16·0	+164·5	8	1918 Feb. 19	
27 9 51 45	+ 5·6	+126·3	5	(see 1918 Feb. 7)	10
28					4
		1918 *March*.			
1					6
2					7
3					8
4					3
5 21 20 25	+25·0	+121·5	3		5
6					6
7					8
8					3

[illegible]				[illegible]	[illegible]	[illegible]		15
26								14
27	2	51	2	+64·8	+ 35·3	11		
27	12	56	35	+36·2	+ 21·4	10		21
28								6
29	11	16	20	+45·6	+ 16·4	2	1917 Jan. 29	5
30	21	18	27	+45·0	+135·0	*65†		8
31								8
				1918 *February.*				
1	12	31	14	+39·3	+ 21·0	5	1917 May 23	9
2								9
3	14	2	30	−18·0	−173·0	24	1917 June 24	
3	14	41	50	− 3·0	− 88·0	8		8
4	0	3	24	+45·8	+ 16·0	3		
4	17	54	49	+29·6	+ 87·8	30		
4	20	38	40	+51·0	−118·0	5		12
5	9	10	56	+44·0	+ 2·5	6		13
6	3	10	30	−11·0	−176·0	13		
6	14	43	42	−11·0	−176·0	6	1918 Feb. 6	8
7	5	20	15	+ 6·5	+127·0	*50†		5
8	18	48	40	+44·0	+ 13·0	7		8
9	12	28	5	+41·5	+ 28·0	18		
9	20	46	10	+45·0	+135·0	13†		10
10								16
11	2	59	45	+39·0	+ 23·0	5	1918 Jan. 20	8
12	1	25	11	+32·2	−110·1	5		
12	1	39	55	+41·0	− 80·0	4		
12	3	0	43	+ 4·5	+ 95·5	*14		
12	19	14	2	+32·2	−110·1	4	1918 Feb. 12	
12	19	33	0	+41·0	− 80·0	5	1918 Feb. 12	
12	20	4	0	+32·2	−110·1	3	1918 Feb. 12	
12	20	9	7	+32·2	−110·1	7	1918 Feb. 12	
12	20	19	28	+41·0	− 80·0	6	1918 Feb. 12	
12	22	46	34	− 2·5	− 11·1	20		9
13	2	31	26	− 5·6	+102·0	*40		
13	6	7	10	+24·0	+116·5	*59		
13	8	27	17	+25·0	+123·0	4	1917 July 4	

9								7
10	14	16	15	−13·0	+136·0	6		3
11	16	25	0	+ 5·0	− 75·0	* 6		
11	21	27	23	+44·5	+ 11·5	4	1916 Aug. 16	9
12								8
13	10	19	55	+41·5	+ 13·8	2		7
14	9	29	15	+ 1·0	+143·5	3	1916 Dec. 26	
14	19	11	55	+38·0	+ 23·7	3		6
15								3
16	13	37	50	+ 1·0	− 70·0	*35		5
17	13	12	37	+36·0	+ 28·0	6	1917 June 13	
17	13	45	5	+36·0	+ 28·0	21	1918 Mar. 17	6
18								3
19	5	55	23	−11·7	+162·5	34		10
20	1	11	15	−13·0	+166·8	9	1914 June 26	12
21	15	50	53	−18·0	+167·0	9	1918 Feb. 19	
21	16	9	20	+47·0	+ 10·0	4	1917 Sept. 6	
21	16	58	22	+ 7·5	− 79·0	11	1913 Oct. 2	15
22	4	43	20	+41·0	+ 14·0	3	1917 Apr. 26	
22	5	51	50	+19·8	+103·3	13		11
23	0	11	50	+49·0	+144·0	11†	1917 July 16	5
24	5	8	40	−18·0	+170·1	10		
24	23	14	54	+34·5	+ 57·1	23		14
25								10
26	6	43	20	+41·0	+ 24·6	8	1917 Aug. 20	5
27	3	52	15	+25·0	+123·0	17		
27	23	11	12	−18·0	+167·0	6	1918 Mar. 21	5
28	7	37	10	+41·0	+ 24·6	5	1918 Mar. 26	8
29								6
30								9
31	0	2	53	+41·0	+ 24·6	6	1918 Mar. 28	14
				1918 *April.*				
1	10	8	18	+22·0	+123·5	5		
1	17	44	5	+33·3	− 9·0	8		12
2	3	33	20	+36·0	+138·0	4	1915 Oct. 8	5
3								7

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

1918 *April*—contd.

d.	h.	m.	s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
4								4
5	15	38	5	+42·0	+ 13·5	5	1915 Jan. 13	6
6								10
7	15	54	10	+42·0	+ 13·5	3	1918 Apr. 5	1
8	5	14	8	+42·0	+ 13·5	2	1918 Apr. 7	12
9								4
10	1	9	0	+38·3	− 76·3	7		
10	2	3	44	+43·4	+128·6	*48†		14
11								4
12								11
13	0	51	12	− 5·0	+ 85·0	*40		9
14								8
15	8	27	40	+59·2	−151·0	20		
15	18	38	10	−13·0	+166·8	8	1914 June 26	12
16								13
17	2	37	38	+46·0	−130·0	*18	1914 July 21	
17	6	43	40	+46·8	−131·3	*22		
17	14	20	25	+40·5	+ 25·5	9		12
18	2	28	40	+24·0	+121·0	4	1916 Nov. 14	
18	2	54	45	+42·0	+ 13·5	2	1918 Apr. 5	
18	20	3	45	+24·0	+121·0	5	1918 Apr. 18	
18	22	14	45	+24·0	+121·0	7	1918 Apr. 18	2
19								9
20								5
21	22	32	20	+33·6	−116·4	*63		
21	23	23	0	+47·0	+ 98·0	5		6
22								11
23	15	27	0	− 4·0	+122·6	10		9
24	14	21	20	+46·4	+ 10·0	16		9
25	2	22	35	+34·5	+ 41·8	22		18
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1918 *May*—contd.

d.	h.	m.	s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
27	16	8	41	(+50·8)	(+ 4·4)	2		5
28	8	21	9	(+50·8)	(+ 4·4)	1		6
29								6
30								9
31	5	5	40	+37·0	+143·0	4	1915 Nov. 18	
31	5	19	0	+37·0	+143·0	6	1918 May 31	
31	8	46	21	+45·1	+147·2	*19		20

1918 *June.*

d.	h.	m.	s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1	5	30	30	−39·0	− 64·0	11		
1	8	23	40	+38·5	+146·0	10	1916 July 16	
1	14	17	30	−10·5	+161·0	15	1917 Nov. 30	14
2								16
3	0	3	12	− 0·4	− 20·0	47		12
4	4	3	23	− 7·0	+145·0	37		
4	17	11	36	−19·0	−177·0	51		10
5	22	29	25	−22·0	+174·0	15	1915 Feb. 25	7
6	18	14	16	−23·3	+150·6	8		5
7	4	54	45	+27·0	+121·0	5	1917 July 5	
7	21	27	6	+18·7	−103·3	*48		11
8	20	13	12	+ 5·0	+128·0	*14	1916 June 9	16
9								8
10	15	35	30	− 4·0	+144·5	16	1916 Aug. 3	8
11	12	36	25	+19·3	− 62·5	23		15
12	4	24	40	+43·0	−125·0	*24	1914 Aug. 22	9
13	8	58	35	+14·5	− 86·0	*16		
13	18	13	55	+39·0	+ 27·0	9	1917 Aug. 8	8
14								13
15								13

27	10	53	0	+40·0	+ 20·0	16	1917 Apr. 26	
27	14	43	45	+ 8·7	− 83·0	19		8
28	11	12	40	+30·5	+ 82·0	12	1916 Oct. 14	7
29								8
30								9

1918 *May.*

1	4	33	12	+35·0	−110·0	6		
1	4	48	5	+41·0	− 77·0	5		7
2	0	0	45	−14·0	−174·0	6	1917 July 11	13
3								8
4	6	6	5	+21·0	+120·0	*32	1917 Aug. 14	12
5								7
6	4	56	55	+36·8	−114·3	18	1915 Oct. 3	
6	8	3	47	+41·7	+ 8·5	7		13
7	6	28	46	+36·0	+139·0	4	1916 Aug. 8	12
8								12
9								7
10								10
11	21	23	4	−27·8	−113·4	*22		12
12								6
13	13	58	3	+42·8	+ 12·3	4	1917 May 19	12
14								16
15								7
16	21	25	35	+18·0	−100·0	*16	1917 Oct. 19	10
17								9
18								9
19	0	25	22	+15·9	+ 83·7	13		16
20	14	35	51	+ 7·4	− 35·2	*72		
20	17	55	5	−29·6	− 71·5	*46†		
20	18	3	39	− 0·5	+152·0	29		7
21	11	15	10	+11·7	+176·0	8		24
22	6	31	20	−17·0	−177·5	39†		15
23	11	57	53	+27·0	−111·3	*60†		13
24								15
25	19	29	25	−31·0	− 91·0	*50†		11
26								10
16	5	11	0	− 8·4	+155·8	19		
16	12	27	36	+15·1	− 84·8	*19	1914 May 28	13
17	16	41	25	+42·5	− 85·5	8		7
18	15	45	15	+41·0	+ 13·0	5		8
19	21	12	8	+39·0	+ 27·0	5	1918 June 13	12
20								8
21	3	59	5	−22·0	−141·0	13†		
21	4	21	20	+32·0	−119·0	6	1917 Nov. 7	
21	5	54	36	+19·0	+144·0	5		16
22	22	5	30	+ 9·5	− 84·0	*19	1916 Apr. 26	9
23								10
24	1	57	28	+42·3	+ 17·8	4		
24	14	46	40	− 1·2	+149·5	23†		9
25								10
26	13	46	3	+35·0	+139·5	*17		
26	21	29	50	−16·0	+168·0	17	1917 Nov. 29	11
27	21	29	30	+53·5	−159·0	*22	1917 July 25	9
28								9
29	4	12	30	+ 7·0	+137·0	9		
29	11	2	0	+42·3	+ 17·8	5	1918 June 24	
29	12	51	10	+42·3	+ 17·8	3	1918 June 29	13
30								7

1918 *July.*

1	6	8	18	+ 9·5	+127·0	*49		
1	11	2	0	+34·5	+ 25·0	14		6
2								19
3	6	51	55	− 3·5	+142·0	*78		8
4	11	25	15	+37·4	+ 30·5	21	1918 Jan. 16	11
5	15	41	20	+37·0	+ 20·5	13		4
6	20	10	22	− 8·0	+146·5	10		10
7								10
8	10	22	7	+26·5	+ 92·0	*76†		13
9	1	55	40	+ 9·3	+129·3	9	1913 Apr. 24	
9	14	1	10	+37·5	+ 19·7	10	1917 Nov. 28	18
10								7

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1918 *July*—contd.			
11 9 48 5	+38·0	+ 21·5	21		16
12					17
13					5
14					14
15 0 22 53	+41·1	−126·6	*46		
15 16 18 36	+ 6·5	+128·0	11	1917 June 6	10
16 11 49 42	+45·5	+ 15·0	7	1916 July 14	
16 20 3 36	+36·3	+ 26·3	*40		21
17					13
18 21 5 5	+36·5	+ 19·7	5		10
19 19 1 0	+45·6	+ 10·2	5		8
20					18
21 6 9 25	− 7·0	+155·0	*69	1917 Dec. 20	
21 9 44 25	− 7·0	+155·0	19	1918 July 21	14
22					12
23 13 22 17	− 4·5	+152·0	21	1917 Sept. 24	5
24 10 53 0	−42·0	+178·0	26		13
25 20 49 55	+35·0	+143·0	*28	1917 Aug. 10	4
26					6
27					14
28					11
29 11 16 39	−18·0	+167·0	14	1917 May 14	
29 16 50 16	− 1·3	+143·4	45		16
30					12
31 14 36 43	+11·0	− 88·0	*51		
31 21 58 45	−12·6	+150·0	18		8
		1918 *August.*			
1 11 42 0	−11·0	−176·0	7	1918 Feb. 6	11
2					5
		1918 *August*—contd.			
26 5 51 28	−30·2	+ 75·0	15		12
27					12
28					5
29 6 39 25	+41·6	+ 35·7	23		15
30					3
31 21 53 35	− 9·0	+111·0	12		7
		1918 *September.*			
1 6 27 55	+38·3	+ 20·0	6	1914 Nov. 27	10
2 14 15 10	0·0	+145·0	30	1917 June 1	8
3					8
4 3 11 50	− 9·0	+111·0	7	1918 Aug. 31	
4 19 54 45	+36·8	−114·3	3	1918 May 6	13
5 7 5 30	+ 5·5	+124·5	24	(1918 Aug. 21)	13
6 3 4 0	+35·0	+ 24·0	8	1915 June 24	
6 12 32 18	+35·0	+ 24·0	11	1918 Sept. 6	11
7 7 14 16	+11·5	+114·0	17	1917 Nov. 13	
7 17 15 51	+46·5	+151·4	*82†		
7 20 26 0	+46·5	+151·4	4	1918 Sept. 7	
7 23 31 51	+12·0	+ 95·0	*12	1918 Jan. 18	28
8 0 9 30	+46·5	+151·4	*26†	1918 Sept. 7	
8 5 40 30	+46·5	+151·4	*32†	1918 Sept. 8	
8 8 30 42	+46·5	+151·4	2	1918 Sept. 8	
8 10 38 9	+46·5	+151·4	2	1918 Sept. 8	
8 11 35 54	+46·5	+151·4	2	1918 Sept. 8	
8 20 18 37	+46·5	+151·4	2	1918 Sept. 8	50
9 11 17 36	+46·5	+151·4	2	1918 Sept. 8	
9 14 20 14	+46·5	+151·4	2	1918 Sept. 9	16
10					15
11 2 27 6	+46·5	+151·4	2	1918 Sept. 9	

4 1 5 7	+44·0	+ 20·0	5		
4 5 4 15	+44·0	+ 20·0	2		14
5 1 37 10	−30·2	−177·7	26	1917 Dec. 9	8
6					14
7					15
8 9 47 48	− 6·0	+153·0	*52†	1913 July 8	13
9 0 38 40	+40·8	+ 35·8	27		11
10 18 44 32	+42·5	+ 7·5	25		12
11 10 49 57	−16·0	+168·0	8	1917 Nov. 29	
11 13 23 25	+45·0	+ 4·8	27		
11 14 2 10	+45·0	+ 4·8	2	1918 Aug. 11	
11 18 2 5	+40·7	+ 14·5	2		
11 23 28 0	+ 5·4	+125·2	6†		3
12 4 58 13	− 8·0	+105·0	7		
13 20 0 50	+45·5	+ 15·0	3	1916 July 14	11
14 13 19 28	+36·0	+ 21·0	8		12
15 12 17 55	+ 5·4	+125·2	*84	1918 Aug. 11	
15 15 26 0	+ 5·4	+125·2	13	1918 Aug. 15	
15 17 30 5	+ 5·4	+125·2	*50	1918 Aug. 15	22
16 3 25 23	+ 5·4	+125·2	*29	1918 Aug. 15	
16 7 22 20	+ 9·0	+110·0	6		
16 8 35 25	+ 5·4	+125·2	*32	1918 Aug. 16	
16 9 25 10	+ 5·4	+125·2	6	1918 Aug. 16	42
17 6 53 28	−18·5	− 63·5	*38		
17 10 25 25	−77·0	+110·0	*8		13
18 6 4 50	+ 5·4	+125·2	14	1918 Aug. 16	20
19 17 27 0	+ 5·4	+125·2	10	1918 Aug. 18	
19 23 57 55	+ 5·4	+125·2	7	1918 Aug. 19	13
20					15
21 0 18 15	+ 5·4	+125·2	7	1918 Aug. 19	
21 4 12 12	+43·4	− 72·0	3		21
22 8 31 0	+20·0	− 99·0	5†	1913 June 14	9
23 6 7 30	−10·0	+ 44·0	20		
23 6 36 33	−11·0	+165·0	51		
23 22 34 30	−15·0	+151·0	11	1918 Feb. 26	13
24					15
25 0 15 50	+37·5	+142·5	5	1916 Aug. 27	14

11 4 0 3	+ 0·5	+120·0	*32		
11 5 56 57	+46·5	+151·4	2	1918 Sept. 11	32
12 9 38 30	+39·5	+ 72·0	17	1916 Apr. 21	
12 13 15 20	+46·5	+151·4	*24†	1918 Sept. 11	
12 18 3 0	+55·0	−160·0	7	1917 June 22	
12 18 25 45	+43·4	− 72·0	6	1918 Aug. 21	17
13 6 54 12	+21·0	+120·0	10	1917 Aug. 14	
13 7 7 40	+21·0	+120·0	10	1918 Sept. 13	
13 7 50 18	+21·0	+120·0	9	1918 Sept. 13	
13 11 3 15	+21·0	+120·0	14	1918 Sept. 13	
13 9 7 35	+40·3	+139·5	7		18
14 17 4 45	+45·0	+152·1	*47		9
15 16 41 6	+34·5	− 10·0	4	1915 July 11	20
16 5 55 45	+21·0	+120·0	7	1918 Sept. 13	
16 13 4 0	−48·5	+162·5	20		14
17					14
18 22 18 35	+21·0	+120·0	6	1918 Sept. 16	7
19					12
20					8
21					5
22 9 54 55	+ 0·5	+100·0	*35	1915 Apr. 3	
22 12 58 13	+46·5	+151·4	4	1918 Sept. 7	
22 13 48 36	+46·5	+151·4	4	1918 Sept. 22	14
23 2 13 20	+36·0	+ 28·0	7	1918 Mar. 17	9
24 0 3 8	+24·0	+121·0	8	1916 Nov. 14	5
25 9 52 20	−16·0	+168·0	4	1917 Nov. 29	8
26 0 16 25	+46·0	+ 9·0	5	1917 Dec. 9	4
27					15
28 10 19 30	−26·0	− 80·0	8	1917 Feb. 21	
28 10 35 20	−26·0	− 80·0	3		4
29 12 7 5	+35·2	+ 34·7	*50		8
30 7 28 5	+35·0	+ 24·0	7	1913 Sept. 30	
30 13 34 20	+51·0	−179·5	*34		
30 16 8 45	+46·5	+151·4	*13	1918 Sept. 8	
30 17 51 35	−24·0	+171·6	*41		
30 18 37 50	− 7 0	+145·0	25	1918 June 4	21

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
			1918 *October*.		
	°	°			
1 0 20 15	+30·0	−174·0	10		
1 1 9 30	−14·0	+ 85·0	*17		5
2 0 20 10	− 5·0	+142·0	24		
2 13 22 27	+13·0	+123·0	4	1917 Sept. 7	6
3					14
4					26
5					6
6					12
7					4
8					9
9 9 17 40	− 7·5	+121·5	*20		9
10					20
11 14 14 25	+18·5	− 68·0	*81	1916 Apr. 24	
11 17 3 34	+18·5	− 68·0	27	1918 Oct. 11	41
12 0 15 30	+18·5	− 68·0	8	1918 Oct. 11	
12 8 19 37	+18·5	− 68·0	14	1918 Oct. 12	33
13 4 51 30	+18·5	− 68·0	7	1918 Oct. 12	
13 12 39 20	−19·0	−177·0	12	1918 June 4	26
14 0 24 20	+18·5	− 68·0	22	1918 Oct. 13	
14 2 15 20	+18·5	− 68·0	8	1918 Oct. 14	
14 12 0 20	−19·5	−174·2	*40		
14 14 6 5	+33·0	+ 22·0	8		7
15 23 29 40	+46·0	−130·0	4	1918 Apr. 17	34
16 20 4 35	− 8·5	+125·5	26		15
17 8 19 3	+18·5	− 68·0	4	1918 Oct. 14	9
18 21 33 35	+18·5	− 68·0	20	1918 Oct. 17	11
19 2 0 20	+15·0	− 97·0	14	1917 Dec. 29	
19 3 22 45	+14·5	− 91·0	*46		12
20 5 44 55	+72·0	− 2·8	6	1917 Aug. 21	15
21					22

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1918 *November*—contd.			
	°	°			
21					22
22 15 48 30	+46·5	+151·4	*31	1918 Sept. 8	8
23 22 57 45	− 8·0	+127·5	*51†	1918 Nov. 18	16
24 19 56 35	+36·0	+138·0	4	1915 Oct. 8	16
25 2 14 7	+46·5	− 28·3	21		
25 12 38 48	+36·4	+ 27·5	6		6
26					13
27					13
28 2 43 2	+36·4	+ 27·5	5	1918 Nov. 25	
28 5 21 17	−31·0	+179·0	*19		16
29 10 41 50	+30·0	+ 71·0	24	1917 Dec. 1	12
30 1 33 30	+22·0	+151·0	4		
30 6 48 31	+70·1	+132·0	36		12
		1918 *December*.			
1 2 35 4	+39·0	+ 73·0	53	(*not* 1917 Apr. 21)	12
2 9 47 21	+10·5	− 44·2	60		16
3 17 51 0	−10·0	+108·0	7		
3 23 6 52	+16·0	+148·0	4		11
4 11 47 44	−26·5	− 70·5	*78		
4 17 41 40	−26·5	− 70·5	*19	1918 Dec. 4	50
5					45
6 7 21 52	−26·5	− 70·5	25	1918 Dec. 4	
6 8 41 3	+49·0	−124·0	*57		
6 11 27 40	−26·5	− 70·5	5	1918 Dec. 6	
6 12 3 0	+49·0	−124·0	18	1918 Dec. 6	15
7 12 39 35	−26·5	− 70·5	7	1918 Dec. 6	8
8					13
9 1 12 30	+46·7	+145·8	*7		

24	19	13	20	− 0·3	+138·8	7	1914 May 26	10
25	3	42	50	+18·5	− 68·0	*47	1918 Oct. 18	
25	19	3	35	+ 5·4	+125·2	8	1918 Aug. 21	10
26	2	13	30	+72·0	− 2·8	11	1918 Oct. 20	
26	16	58	40	+ 5·4	+125·2	6	1918 Oct. 25	8
27	15	27	10	−10·5	+161·0	*57	1917 Nov. 30	
27	17	6	30	− 1·2	+149·5	*57	1918 June 24	9
28								13
29	12	26	0	+ 8·0	− 84·0	16	1917 June 30	7
30								4
31								11
				1918 *November.*				
1								10
2	10	1	10	+19·4	−155·3	12		10
3	11	13	50	−48·2	+165·8	*40		13
4								10
5	22	39	0	+12·0	− 95·5	12	1918 Jan. 25	14
6	19	26	0	+44·6	+ 13·3	16		9
7								11
8	4	38	0	+44·9	+151·4	*75		7
9								10
10	15	11	40	+45·0	+11·5	30		
10	17	58	3	+34·6	+140·7	9		32
11	7	3	0	+36·1	+137·3	*25	1917 Feb. 21	29
12	12	1	35	+18·5	− 68·8	4		
12	21	44	32	+18·2	− 68·2	*45		23
13	10	13	27	+37·5	+27·5	13		10
14	12	52	35	− 1·3	+143·4	11	1918 July 29	
14	16	6	50	+47·0	+158·0	11		7
15								9
16	5	56	30	+12·0	− 95·5	*8	1918 Nov. 5	12
17								7
18	18	41	45	− 8·0	+127·5	*77		17
19								12
20	7	33	0	+40·0	+ 20·0	8	1917 Oct. 18	8

9	18	3	45	+52·0	−178·0	*35		
9	18	52	47	+52·0	−178·0	*32		13
10								17
11	17	46	42	+ 0·5	− 82·0	10	1917 May 3	10
12								9
13	1	18	40	−26·5	− 70·5	6	1918 Dec. 9	16
14	18	39	15	−13·0	+166·8	17†	1918 Mar. 20	16
15								4
16	3	3	20	+12·0	+ 95·0	11	1918 Jan. 18	
16	10	11	20	+26·3	+121·5	*9		
16	20	20	10	+14·0	+ 60·0	5	1917 Dec. 5	11
17								6
18	17	15	55	+25·0	+119·5	6	1918 Jan. 15	12
19	19	23	0	−11·0	+165·0	13	1918 Aug. 23	5
20								8
21	9	24	40	+ 1·0	− 70·0	26	1918 Mar. 16	14
22	21	2	13	+38·5	+142·5	7		4
23	19	40	15	+33·6	−116·4	18	1918 Apr. 21	15
24								11
25	10	21	10	− 7·0	+153·0	*33†		11
25	10	31	45	+41·5	− 7·0	4		
26								10
27								11
28	8	9	20	−13·0	+136·0	7	1918 Mar. 10	
28	18	3	10	− 3·3	− 12·0	17		14
29								7
30	7	11	45	− 4·5	+152·0	9	1918 July 23	4
31								14
				1919 *January.*				
1	1	33	36	+ 5·4	+125·2	*74	1918 Oct. 26	
1	3	0	0	−20·5	−178·5	*76†		19
2								15
3								20
4	14	17	37	+ 5·4	+125·2	4	1919 Jan. 1	19
5	15	25	30	+40·0	+ 20·0	17	1918 Apr. 27	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1919 *January*—contd.					
	°	°			
5 19 51 40	−29·6	− 71·5	33	1918 May 20	4
6 22 24 10	−11·7	+162·5	40		13
7					13
8 1 46 50	+25·0	− 46·0	14		
8 10 12 53	+40·0	+ 47·0	6		
8 21 45 20	−11·7	+162·5	4	1919 Jan. 6	6
9					8
10					16
11 9 35 10	+14·5	+145·5	7	1917 June 18	5
12 13 21	+35·7	+139·8	4		6
12 15 25 55	−22·0	+170·0	4		
13					8
14					7
15					7
16					5
17 11 49 50	+16·0	− 96·0	18	1917 Mar. 6	12
18 5 52 30	− 3·5	+102·5	25	1916 Apr. 15	8
19					13
20					4
21					22
22 3 24 20	+41·0	+ 24·6	3	1918 Mar. 31	13
23					8
24 3 25 50	+36·0	+139·0	4	1918 May 7	7
25					9
26					6
27 21 38 20	+50·0	−175·0	*20		11
28					6
29					6
30					6
31 23 43 15	+41·0	−127·0	24	1917 June 10	7

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1919 *March*—contd.					
	°	°			
2 16 56 50	+34·0	+ 96·0	4	1915 Apr. 28	6
3					14
4 8 1 25	−48·0	+134·0	*17		9
5					7
6 3 13 53	− 3·4	+118·5	7		
6 13 12 4	+36·7	+ 21·0	6		11
7					10
8					10
9 3 16 45	−41·0	− 74·0	*55†	1919 Mar. 2	9
10 21 19 45	+27·5	+123·5	19		9
11					7
12 10 31 5	+44·5	+140·0	6		12
13 13 9 30	+45·0	+120·0	3	1917 July 31	
13 14 16 55	− 8·5	+124·5	*7		11
14					18
15					11
16 7 33 10	+ 9·5	+127·0	*39†	1918 July 1	
16 15 3 0	+ 9·5	+127·0	8†	1919 Mar. 16	9
17					13
18					4
19					17
20					9
21 1 2 15	+13·0	+123·0	*30	1917 May 28	
21 16 1 56	− 8·5	+149·0	*32	1917 Oct. 29	
21 17 20 25	+ 8·0	+128·0	8	1913 Apr. 18	
21 17 30 10	+ 8·0	+128·0	15	1919 Mar. 21	12
22 16 18 45	−18·0	+170·1	*13	1918 Mar. 24	18
23 22 51 35	+ 9·5	+123·0	5		6
24					5
25					11
26 13 34 50	+30·6	+141·8	3	1917 July 10	11

1								11
2	20	2	50	+72·0	− 2·8	37	1917 Aug. 21	8
3	2	23	20	+52·0	+170·0	6	1917 Nov. 14	14
4								3
5	20	4	15	+34·5	+138·0	15	1916 Sept. 15	10
6								16
7								2
8								17
9	12	45	20	+30·6	+144·0	10	1913 Apr. 7	
9	15	24	30	+30·6	+144·0	8	1919 Feb. 9	13
10								8
11								6
12	12	41	55	+46·0	+149·0	*38	1917 Apr. 28	
12	20	47	30	+46·0	+149·0	*24	1919 Feb. 12	8
13								10
14	15	9	20	+47·5	+129·0	8	1918 Jan. 30	9
15	2	17	17	+68·2	− 13·0	23		4
16	15	57	53	+37·7	−118·5	11		2
17	17	57	20	− 3·0	+128·0	*11		10
18	3	44	15	+37·2	+139·0	4		7
19								7
20	12	32	55	−27·0	− 72·0	6	1913 May 24	2
21								5
22	4	16	41	+46·5	+151·4	*23	1918 Nov. 22	12
23								12
24	1	56	0	+36·7	+ 21·0	32		3
25	22	38		(+37)	(−118)	3		18
26								5
27								6
28								5

1919 *March.*

1	13	36	0	+ 9·0	+141·0	24†		10
2	3	26	40	−41·0	− 74·0	*62†		
2	11	45	10	−41·0	− 74·0	*58†	1919 Mar. 2	
28	22	40	18	+37·0	+138·5	4		5
29								12
30	10	39	52	+ 9·0	+141·0	13†	1919 Mar. 1	4
31								7

1919 *April.*

1								20
2	0	34	48	− 6·0	+105·0	*43		6
3								14
4								11
5	4	17	55	+37·0	+ 26·0	4	1917 Aug. 27	12
6								9
7								12
8								5
9								8
10								10
11								2
12								9
13								4
14								9
15	23	52	43	+37·2	+139·0	4	1919 Feb. 18	15
16	3	13	53	−39·0	− 17·0	*20		
16	16	39	45	+ 6·5	+128·0	11	1918 July 15	12
17	11	22	2	−30·2	−179·0	*65		
17	20	53	5	+14·5	− 91·0	*66†	1918 Oct. 19	11
18	6	20	12	+46·0	+ 25·0	11	1916 Jan. 26	
18	21	0	57	+19·6	−106·5	*42		5
19	2	57	2	+17·0	− 97·0	11	1917 Mar. 5	2
20								5
21	11	25	54	+ 8·0	− 40·5	54		20
22	2	43	38	+ 1·0	+147·0	25		12
23	7	5	10	−19·0	−177·0	25	1918 Oct. 13	4
24	17	10	32	− 6·0	+105·0	16	1919 Apr. 2	12
25								13
26								10
27	0	21	55	+13·0	+123·0	*45	1919 Mar. 21	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1919 *April*—contd.					
d. h. m. s.	°	°			
27 2 33 35	+25·0	+141·5	6		7
28 6 45 45	+14·5	− 91·0	23	1919 Apr. 17	12
29					18
30 7 16 55	−21·2	−172·5	*81†		17
1919 *May*.					
1 1 20 45	+26·0	+143·0	9		
1 5 5 33	−10·0	+ 36·0	*49		46
2 2 7 10	−21·2	−172·5	*51	1919 Apr. 30	20
3 0 51 55	+40·7	+145·8	*74†		11
4 18 30 38	+34·6	+140·7	5	1918 Nov. 10	
4 22 0 12	+21·1	+121·7	5	1918 Apr. 26	
4 22 42 38	−21·2	−172·5	19	1919 May 2	9
5 20 27 45	+55·0	− 35·0	7	1917 Mar. 3	28
6 4 8 50	−21·2	−172·5	21	1919 May 4	
6 19 40 45	− 6·0	+153·0	*77†	1918 Aug. 8	14
7 5 13 38	− 6·0	+153·0	38		26
8 10 7 30	−21·2	−172·5	25	1919 May 6	29
9					15
10 5 15 0	+32·7	+129·9	2		13
11					13
12					12
13					3
14					11
15					9
16 1 0 0	+21·0	+127·0	*17	1915 July 2	
16 11 44 20	+45·0	+135·0	5	1918 Jan. 30	
16 21 1 35	+24·0	+123·0	5		8
17					6
18 10 23 56	+56·0	−136·0	10		

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1919 *June*—contd.					
d. h. m. s.	°	°			
14					8
15 18 49 4	+30·0	+ 71·0	15	1919 June 1	15
16					7
17					8
18					19
19					10
20					16
21					12
22					5
23 6 26 10	+41·0	+144·0	10	1917 Nov. 15	4
24 18 34 30	+17·3	+120·5	*14		13
25					6
26 18 58 0	+34·5	− 10·0	8	1918 Sept. 15	10
27					5
28 4 40 50	− 4·5	+131·0	16	1915 May 5	
28 10 26 53	+35·0	+ 90·5	12		11
29 8 14 37	+43·8	+ 11·2	14		
29 15 6 12	+43·8	+ 11·2	35	1919 June 29	
29 16 36 15	+43·8	+ 11·2	10	1919 June 29	
29 23 14 15	+14·5	− 86·0	*57	1918 June 13	64
30 7 23 40	+ 6·0	+ 37·0	6		
30 7 26 20	+ 6·0	+ 37·0	*41	1919 June 30	
30 23 50 40	+43·8	+ 11·2	9	1919 June 29	21
1919 *July*.					
1 3 34 30	+43·8	+ 11·2	11	1919 June 30	
1 21 30 25	+14·5	− 91·0	6	1919 Apr. 28	
1 21 49 36	+50·0	−128·0	3	1917 Dec. 23	8
2 7 21 10	+34·0	+131·0	7		20

19	3	55	54	+19·0	+144·0	14	1918 June 21	7
20	4	20	12	+40·5	−122·0	28†		
20	4	31	5	+19·0	− 70·0	7†		10
21								11
22	11	52	36	+52·0	−178·0	*33	1918 Dec. 9	12
23	3	7	35	− 8·2	− 79·3	*20		
23	6	10	38	+30·0	+ 71·0	35	1918 Nov. 29	
23	18	8	40	+30·0	+ 71·0	6	1919 May 23	16
24								11
25								7
26								8
27	10	34	20	+37·2	+ 35·4	20		
27	17	27	3	+54·0	+161·0	*23		6
28	3	3	55	+53·5	+163·5	*11		
28	5	39	22	+37·0	+ 20·5	6	1918 July 5	8
29	10	59	45	+31·5	+100·5	34†		7
30								8
31	16	2	40	+33·2	+138·0	8		8
				1919 *June.*				
1	6	51	13	+25·7	+124·8	*31†		
1	12	46	20	+30·0	+ 71·0	8	1919 May 23	15
2								10
3	7	24	28	+37·0	+ 20·5	6	1919 May 28	15
4								16
5								12
6								7
7	23	6	30	+26·0	+143·0	6	1919 May 1	18
8	23	14	15	+34·6	+140·7	5	1919 May 4	16
9	7	13	35	+41·5	+ 34·0	30		
9	14	16	10	+30·5	+133·3	4		
9	15	47	15	+41·5	+ 34·0	12	1919 June 9	5
10	20	9	15	+ 4·0	+144·0	9	1917 June 18	17
11								17
12								18
13								11

4	13	29	20	− 7·4	+ 35·9	18		23
5								10
6	7	4	10	+14·5	− 91·0	*27	1919 July 1	
6	19	29	3	−11·5	− 64·0	2		8
7	13	55	0	− 2·0	+137·0	15	1916 Jan. 13	5
8	5	53	40	+43·8	+ 11·2	19	1919 July 1	
8	21	6	0	− 7·4	+ 35·9	*59	1919 July 4	20
9	16	20	35	+36·0	+141·0	3		
9	19	19	25	+17·0	−112·0	21		14
10	2	22	10	+50·0	−128·0	7	1919 July 1	11
11	0	30	30	+ 8·0	− 72·0	22		
11	4	9	25	+ 8·0	− 72·0	3	1919 July 11	
11	18	3	50	+ 8·0	− 72·0	1	1919 July 11	12
12	12	4	30	+42·5	+ 7·5	3	1918 Aug. 10	
12	22	28	0	+55·0	− 35·0	18	1919 May 5	12
13								6
14	13	44	50	+52·0	−178·0	*21	1919 May 22	
14	14	22	0	+40·0	+ 60·0	6		11
15	5	25	30	+45·1	+147·2	6	1918 May 31	7
16	4	9	15	+45·1	+147·2	12	1919 July 15	
16	18	6	30	−16·0	−171·0	9	1917 June 28	9
17	9	49	5	+24·0	+121·0	25	1918 Sept. 24	
17	16	19	34	+11·0	− 88·0	23	1918 July 31	20
18	2	28	0	+39·5	− 27·0	4	1917 June 30	
18	7	1	20	+36·0	+ 28·0	7	1918 Sept. 23	
18	13	37	0	+43·0	−125·0	6	1918 June 12	
18	15	7	0	+24·0	+121·0	6	1919 June 17	15
19								7
20	0	3	50	+36·0	+ 28·0	5	1919 July 18	9
21	19	3	53	− 3·0	+100·9	*10		
21	23	49	20	+42·0	+141·0	3		4
22	22	1	25	+13·0	− 83·0	*25	1917 Oct. 22	9
23								6
24	2	3	20	+40·0	+ 76·0	*49		
24	4	43	55	− 1·5	− 76·0	7		
24	20	46	30	+24·0	+121·0	2	1919 July 18	11
25	3	17	50	+38·5	+ 22·5	1†	1917 Mar. 14	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

1919 *July*—contd.

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	°	°			
25 3 43 0	+35·0	+139·5	1†	1918 June 26	
25 18 56 0	+10·0	−103·0	12		7
26 13 47 40	+35·0	+143·0	3	1918 July 25	7
27 21 49 10	+36·0	+134·0	3		5
28					9
29 13 27 40	− 8·0	+105·0	3	1918 Aug. 12	
29 19 25 0	+33·3	− 9·0	7	1918 Apr. 1	5
30					13
31 21 52 50	+53·5	−159·0	11	1918 June 27	28

1919 *August.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1					8
2					9
3 9 45 0	+31·5	+ 19·5	7		
3 18 8 40	+35·0	+143·0	*24	1919 July 26	
3 20 27 8	+35·0	+143·0	3	1919 Aug. 3	
3 20 53 7	+35·0	+143·0	4	1919 Aug. 3	
3 21 15 52	+35·0	+143·0	5	1919 Aug. 3	19
4					4
5					9
6					14
7 6 50 50	+24·0	+121·0	7	1919 July 24	
7 16 31 25	+38·5	+146·0	12	1918 June 1	6
8 5 1 10	−21·0	− 67·0	*19	1917 Nov. 2	7
9 12 25 35	−21·0	− 67·0	5	1919 Aug. 8	
9 14 38 0	+48·5	+ 28·0	7†		
9 22 41 30	+33·3	− 9·0	13	1919 July 29	9
10					6
11 5 5 0	−51·5	− 75·5	5		9

1919 *September*—contd.

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	°	°			
3					14
4					7
5 7 52 20	+32·0	+ 74·0	6		
5 16 52 12	+18·0	+133·0	10		
5 19 2 10	+19·5	− 65·0	7		
5 20 37 20	+47·5	+ 15·8	4	1917 Aug. 8	21
6 9 29 45	+19·5	− 65·0	31	1919 Sept. 5	20
7 18 21 43	+24·0	+120·0	4	1917 Jan. 4	
7 20 21 16	−29·0	− 98·0	5		5
8 4 8 0	+18·0	+ 97·0	8	1917 Apr. 12	
8 14 4 10	+24·0	+120·0	4	1919 Sept. 7	15
9					9
10 10 40 0	+41·5	− 7·0	10†	1918 Dec. 25	
10 10 44 30	+44·0	+ 2·5	8	1918 Feb. 5	
10 10 56 5	+41·5	− 7·0	10	1919 Sept. 10	
10 11 0 35	+44·0	+ 2·5	6	1919 Sept. 10	
10 11 58 30	+41·5	− 7·0	6	1919 Sept. 10	
10 12 3 0	+44·0	+ 2·5	1	1919 Sept. 10	
10 14 21 50	+41·5	− 7·0	5	1919 Sept. 10	
10 14 26 20	+44·0	+ 2·5	3	1919 Sept. 10	
10 16 57 20	+43·0	+ 12·5	24	1917 May 11	13
11 0 38 0	+41·5	− 7·0	3	1919 Sept. 10	
11 5 31 0	+24·5	+143·5	4	1917 July 1	
11 13 47 50	+11·5	+144·0	4	1918 Jan. 12	
11 13 49 30	+19·0	− 68·0	4	1917 July 27	
11 14 11 30	+19·0	− 68·0	2	1919 Sept. 11	11
12 6 5 40	−42·0	+178·0	18	1918 July 24	
12 12 23 40	−42·0	+178·0	4	1919 Sept. 12	
12 13 49 40	+48·0	+148·0	*21		
12 14 26 37	+72·0	− 2·8	5	1919 Feb. 2	

14								12
15	2	6	30	+34·6	+140·7	3	1919 June 8	
15	4	17	26	−31·0	− 43·0	*13		17
16								9
17								9
18	11	17	30	+51·0	− 34·0	9	1917 Apr. 20	
18	16	55	25	−17·0	−177·5	52†	1918 May 22	
18	20	52	0	−17·0	−177·5	8†	1919 Aug. 18	15
19	14	20	55	+18·5	+120·0	3	1917 Sept. 17	
19	20	17	20	+35·2	+ 34·7	14	1918 Sept. 29	20
20								15
21								20
22	8	50	15	+19·0	− 70·0	4	1919 May 20	
22	22	35	55	+41·0	+ 24·6	21	1919 Jan. 22	15
23	5	22	30	+24·0	+121·0	2	1919 Aug. 7	
23	7	52	30	+24·0	+121·0	3	1919 Aug. 23	12
24	1	45	55	+41·7	+ 8·5	2	1918 May 6	
24	5	13	40	+43·0	−125·0	11	1919 July 18	
24	18	16	18	+36·0	+ 28·0	8	1919 July 20	24
25	19	55	15	+32·0	+100·0	25		13
26								13
27	1	1	56	+24·0	+121·0	2	1919 Aug. 23	
27	5	21	18	+19·0	+144·0	37	1919 May 19	10
28	19	34	22	+24·0	+121·0	*14	1919 Aug. 27	8
29	5	43	45	− 3·5	+128·5	57		
29	6	41	30	+36·2	+ 21·4	2	1918 Jan. 27	
29	13	46	45	−15·0	+165·0	15		7
30	6	4	0	+19·3	− 62·5	5	1918 June 11	13
31	0	24	40	+59·2	−151·0	3	1918 Apr. 15	
31	2	32	48	+34·5	+ 41·8	6	1918 Apr. 25	
31	17	20	34	−15·7	+167·3	*66†		7

1919 *September.*

1	13	14	30	−22·0	+170·0	9	1919 Jan. 12	
1	19	12	25	−69·0	−108·0	23		13
2								5
13	12	20	8	−15·2	− 61·0	*14	1919 Sept. 13	
13	17	29	10	−15·2	− 61·0	7	1919 Sept. 13	
13	18	11	30	+44·0	− 20·0	6	1918 Jan. 14	
13	21	49	10	+18·2	− 68·2	5	1918 Nov. 12	32
14	1	43	0	−15·2	− 61·0	1	1919 Sept. 13	
14	3	40	30	−15·2	− 61·0	1	1919 Sept. 13	
14	6	17	30	+18·2	− 68·2	3	1919 Sept. 13	16
15	17	30	55	+21·0	−106·5	*28	1917 June 29	21
16	2	18	37	+46·4	+ 10·0	3	1918 Apr. 24	
16	11	48	0	−15·2	− 61·0	12†	1919 Sept. 14	9
17								5
18								13
19	3	13	40	+59·2	−151·0	7	1919 Aug. 31	41
20	8	52	48	+44·5	+ 11·5	5	1918 Mar. 11	6
21								20
22								17
23	20	40	35	−48·6	−113·3	8		15
24								13
25								18
26	6	25	34	+22·5	+116·5	4		
26	7	20	30	+17·3	+120·5	4	1919 June 24	
26	9	6	50	+17·3	+120·5	*43	1919 Sept. 26	
26	19	39	20	+ 6·3	+123·2	*42		
26	21	38	0	+ 6·3	+123·2	12	1919 Sept. 26	
26	22	48	20	+ 6·3	+123·2	12	1919 Sept. 26	4
27	3	33	50	+ 7·0	− 82·5	12		22
28								12
29	13	41	20	+25·0	+123·0	6	1918 Mar. 27	19
30	7	37	8	+28·0	−112·5	6		
30	7	52	32	+38·0	− 82·5	5		16

1919 *October.*

1	19	31	2	+33·6	−116·4	10	1918 Dec. 23	7
2								6
3	9	37	20	−16·5	180·0	43		6
4	17	50	0	+ 2·0	+ 83·0	15		20

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

1919 *October*—contd.

d.	h.	m.	s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
5								12
6								4
7	9	13	0	+44·0	+ 20·0	5	1918 Aug. 4	6
8	4	40	30	0·0	+145·0	39	1918 Sept. 2	
8	22	35	20	+17·5	− 47·5	9		14
9	6	51	20	− 3·5	+102·5	14	1919 Jan. 18	
9	17	7	23	+41·0	+ 24·6	7	1919 Aug. 22	
9	21	38	18	+41·0	+ 24·6	7	1919 Oct. 9	15
10	1	7	20	+49·0	−124·0	*37	1918 Dec. 6	13
11	13	17	25	+41·0	+139·0	*24		8
12	21	48	15	− 4·0	+101·0	*49†		12
13	7	54	10	+41·5	+ 28·0	11	1918 Feb. 9	
13	13	4	10	+41·5	+ 28·0	10	1919 Oct. 13	17
14	16	55	40	+11·0	− 88·0	10	1919 July 17	13
15	15	45	40	+23·3	+122·0	11		8
16								5
17								7
18								16
19	1	32	28	−16·5	180·0	9	1919 Oct. 3	8
20								8
21	0	24	50	+41·1	+ 14·0	12	1918 Mar. 22	
21	5	41	45	−26·0	+ 38·0	7	1915 June 8	
21	21	21	0	− 7·0	+148·0	23	1913 Oct. 11	7
22	6	5	30	+40·0	+ 14·0	25		9
23	16	3	5	+ 2·1	+127·8	9	1918 Oct. 22	16
24	20	32	15	+27·5	+ 63·6	13		9
25	13	50	25	+40·0	+ 14·0	16	1919 Oct. 22	
25	17	10	0	+37·0	+ 26·0	30	1919 Apr. 5	
25	17	53	20	+37·0	+ 26·0	11	1919 Oct. 25	22
26	18	4	32	+ 2·1	+127·8	2	1919 Oct. 23	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16

1919 *November*—contd.

d.	h.	m.	s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
28	14	8	0	+55·0	− 35·0	23	1919 July 12	
28	21	38	10	+43·5	+ 7·5	15		2
29	0	25	20	+40·8	+ 0·5	14		
29	0	26	30	+40·8	+ 0·5	3	1919 Nov. 29	5
30								10

1919 *December*.

d.	h.	m.	s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1								4
2								13
3								8
4								10
5	0	15	26	+ 13·0	− 85·4	14		5
6								6
7								7
8								8
9	20	23	15	+19·8	+103·3	7	1918 Mar. 22	
9	20	28	6	+26·0	+114·0	3	1917 Jan. 27	8
10								7
11								9
12								23
13								3
14	1	10	5	−29·2	−177·0	*28	1917 May 9	8
15								16
16	11	41	25	+24·0	+124·0	11	1916 Mar. 25	5
17								10
18	1	20	35	+20·0	− 99·0	6	1918 Aug. 22	5
19								5
20	0	28	15	+37·0	+138·5	9	1919 Mar. 28	
20	10	34	0	+23·0	+121·7	*39		

28	7	23	20	+13·0	− 83·0	7	1919 July 22	9
29								15
30								4
31	15	36	20	−27·0	+ 31·5	*27		
31	19	2	10	+24·0	+116·5	*28	1918 Feb. 13	
31	23	34	0	(+34·7)	(+135·2)	4		10
				1919 *November.*				
1								16
2	19	30	24	+65·0	− 41·0	10		22
3								10
4								18
5								21
6	7	13	10	+13·5	− 59·0	21†		18
7								6
8								9
9								6
10								8
11								4
12								21
13								13
14	6	38	35	+11·0	−108·0	6		17
15								13
16	3	5	33	+15·5	+109·0	6		7
17								7
18	3	58	35	− 4·5	+131·0	32	1919 June 28	
18	21	54	38	+39·6	+ 27·7	*53		6
19								6
20	14	11	38	−13·0	+166·8	*50†	1918 Dec. 14	15
21	2	6	24	−22·0	+114·7	5		15
22								10
23	5	57	30	0·0	+135·0	23		9
24								14
25								6
26								6
27								7

20	21	38	55	+23·0	+121·7	8	1919 Dec. 20	6
21								9
22	23	40	48	+39·3	+ 21·0	32	1918 Feb. 1	9
23								20
24								10
25	21	42	20	+45·0	+ 36·0	14		5
26								17
27								11
28								10
29								6
30								8
31								4
				1920 *January.*				
1	12	7	0	−18·0	+173·5	20		24
2	13	17	15	+46·0	−130·0	5	1918 Oct. 15	6
3	0	51	28	+40·0	+141·5	5		12
4	4	21	58	+18·2	− 97·5	*40		20
5								12
6	3	50	32	+40·0	+141·5	4	1920 Jan. 3	9
7								21
8								9
9	11	58	57	+43·2	+ 29·3	13		11
10								9
11								21
12	2	52	20	+18·0	+133·3	5	1919 Sept. 5	
12	13	39	52	+22·3	+143·2	27		18
13	18	30	40	+40·3	+139·5	13	1918 Sept. 13	
13	23	0	28	− 9·5	+157·0	26		15
14	14	38	20	− 7·2	+150·0	21		26
15	11	48	5	+11·5	+144·0	7	1919 Sept. 11	
15	16	25	27	+19·0	− 70·0	4	1919 Aug. 22	13
16								6
17	18	48	15	+40·3	+139·5	13	1920 Jan. 13	20
18								4
19								5

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1920 *January* contd.			
	°	°			
20 1 42 5	− 8·0	+127·5	8†	1918 Nov. 23	14
21 6 0 50	+ 5·0	+148·0	12		12
22 21 19 10	−16·0	+168·0	16	1918 Sept. 25	
22 21 44 30	+25·5	+122·0	5		8
23					14
24					17
25 3 50 50	+25·5	+122·0	7	1920 Jan. 22	15
26 11 14 50	+ 2·1	+127·8	6	1919 Oct. 26	
26 23 1 40	+19·0	− 70·0	5	1920 Jan. 15	13
27					12
28					8
29 21 44 47	−18·0	+170·1	7	1919 Mar. 22	5
30 18 26 45	+ 4·5	− 77·5	*31		
30 19 33 10	−17·0	−177·5	14	1919 Aug. 18	8
31					9
		1920 *February.*			
1 13 24 40	− 7·0	+150·0	13		17
2 11 22 15	− 7·0	+150·0	*77	1920 Feb. 1	27
3 14 53 0	− 7·0	+150·0	13	1920 Feb. 2	37
4					20
5					13
6					13
7 11 50 30	+56·8	− 33·6	35		
7 15 7 10	+40·3	+139·5	20	1920 Jan. 17	
7 15 24 28	− 7·0	+150·0	12	1920 Feb. 3	18
8 5 24 12	−35·0	+111·0	27		14
9 2 31 18	− 7·0	+150·0	7	1920 Feb. 7	
9 19 2 20	− 1·2	+149·5	11	1918 Oct. 27	9
10 9 12 45	−11·7	+162·5	26	1919 Jan. 8	

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1920 *March*—contd.			
	°	°			
5					5
6					6
7					7
8 15 14 41	+43·8	+ 11·2	5	1919 July 8	13
9 4 34 20	+17·0	− 97·0	6	1919 Apr. 19	8
10					13
11 11 46 55	−53·8	+148·0	14		
11 18 32 54	−30·2	−179·0	7	1919 Apr. 17	4
12 15 20 15	+ 6·5	+128·0	17	1919 Apr. 16	19
13 3 58 55	+11·5	+144·0	11	1920 Jan. 15	
13 10 39 40	+24·0	+123·0	10	1919 May 16	21
14					14
15 12 5 30	−20·0	+176·5	*40†		11
16					15
17 18 36 50	+ 2·0	+ 96·0	*21		7
18					8
19					19
20 17 48 42	+40·5	−122·0	18	1919 May 20	
20 18 31 15	−35·8	−109·4	*61		16
21					17
22 1 38 33	− 8·0	+160·0	13	1917 Nov. 22	
22 20 1 43	−17·0	−177·5	36†	1920 Jan. 30	19
23 15 21 48	+14·5	− 91·0	*32	1919 July 6	6
24					12
25					12
26					4
27					8
28					13
29 5 7 40	+50·5	−129·5	*41		10
30 1 4 15	+46·0	+ 9·0	6	1918 Sept. 26	12
31					14

10	22	7	10	+19·0	− 68·0	66	1919 Sept. 11	24
11								13
12	0	26	15	+19·0	− 68·0	11	1920 Feb. 10	
12	17	49	10	+19·0	− 68·0	8	1920 Feb. 12	21
13								10
14								8
15	2	36	43	(+45)	(+ 12)	3		
15	4	56	18	(+45)	(+ 12)	3	1920 Feb. 15	12
16								10
17								10
18	10	31	32	+37·0	+138·5	4	1919 Mar. 28	12
19	4	47	50	+37·0	+138·5	3	1920 Feb. 18	
19	4	58	50	+37·0	+138·5	4	1920 Feb. 19	
19	19	54	0	−48·5	−160·5	9		11
20	0	1	30	+42·0	+ 46·0	15		
20	11	44	25	+42·0	+ 46·0	33	1920 Feb. 20	7
21								22
22	17	35	40	+46·7	+145·8	*46†	1918 Dec. 9	9
23								11
24								9
25	17	56	18	+35·0	+ 10·0	22		
25	22	39	48	+ 6·5	+127·0	27	1918 Feb. 7	
25	23	32	20	+38·8	+ 32·9	15	1918 Jan. 16	11
26	1	26	0	+ 5·0	+110·0	15†		
26	23	4	3	+38·8	+ 32·9	9	1920 Feb. 25	14
27	3	51	36	+35·0	+ 69·0	25		
27	7	10	54	−18·0	+167·0	12	1918 July 29	
27	10	34	56	−18·0	+167·0	8	1920 Feb. 27	14
28	18	41	0	−12·0	− 69·0	*27		
28	19	49	15	+45·0	+ 11·5	4	1918 Nov. 10	22
29								15
				1920 *March.*				
1								16
2								7
3	10	43	25	− 8·0	+127·5	5†	1920 Jan. 20	5
4								6

1	18	26	38	+46·0	+ 9·0	4	1920 Mar. 30	18
2	1	5	0	−10·2	+143·4	26		
2	15	10	0	+ 7·0	+137·0	21	1918 June 29	
2	15	34	20	+37·5	+ 27·5	15	1918 Nov. 13	14
3								5
4								13
5	12	18	26	+41·0	+ 13·5	8		
5	15	52	20	− 4·0	+138·0	17	1915 Aug. 3	14
6	16	43	20	+15·6	− 97·8	*19		
6	19	2	25	− 5·0	+155·0	30†	1913 July 22	21
7								6
8								12
9								17
10								8
11	23	3	35	+48·3	+152·0	*40		22
12								19
13								12
14								8
15	12	13	30	+33·0	+139·0	8		5
16	22	35	15	+57·3	−165·0	23		3
17								6
18	21	1	45	+57·3	−165·0	12	1920 Apr. 16	13
19	21	6	25	+18·4	− 94·3	*48		10
20								7
21								11
22								12
23								20
24								9
25	16	45	0	+ 4·0	+130·0	6	1913 Mar. 26	14
26								10
27								11
28								9
29								24
30								11

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1920 *May*.					
1 6 34 40	+37·0	+ 28·7	9		18
2 8 27 50	+35·0	+ 90·5	30	1919 June 18	
2 14 46 40	+35·0	+ 90·5	31	1920 May 2	11
3					10
4					11
5 14 41 55	+45·5	+ 15·0	16	1918 Aug. 13	18
6 9 40 30	+44·0	+131·0	11†	1918 Apr. 10	11
7 5 40 40	+ 6·5	+126·0	*55	1918 Sept. 11	
7 21 31 10	− 8·4	+155·8	*65	1918 June 16	12
8 21 3 50	+56·0	−136·0	13	1919 May 18	24
9 8 0 4	−51·7	+173·8	9		
9 17 9 20	+ 9·8	+126·2	11		12
10 18 49 40	− 5·5	+130·0	*47†		10
11					12
12 21 53 12	+38·0	+136·0	*25		10
13 1 48 25	− 4·0	+144·5	*63	1918 June 10	
13 4 40 40	+49·8	+ 12·0	5		3
14 17 57 10	+64·1	− 27·5	20	1914 June 19	10
15					20
16 21 11 15	+ 7·5	+121·5	9		12
17					10
18					16
19 3 11 0	+ 3·0	+122·0	19	1913 Jan. 11	
19 3 21 30	+34·0	+ 21·0	7		
19 12 41 33	− 6·5	+126·0	25		11
20 4 36 35	−65·0	− 39·0	9		
20 7 25 55	−11·7	+166·3	*54		7
21 19 19 15	+34·0	+131·0	4	1919 July 2	16
22 17 4 4	+35·0	+139·5	7	1918 June 26	
22 17 8 50	−23·0	+142·0	11		13

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1920 *June*—contd.					
15 14 2 15	+43·0	+ 15·0	6	1920 May 30	16
16 16 47 25	+24·0	+120·0	9	1920 June 5	11
17					12
18 10 8 3	+33·0	−121·5	12		15
19					10
20 12 14 56	+43·5	+ 17·0	18		20
21 7 21 35	+43·0	+ 15·0	7	1920 June 15	14
22 2 48 6	+33·0	−121·5	11	1920 June 18	
22 8 9 51	+34·5	+138·0	4	1919 Feb. 5	7
23					9
24 5 48 45	+64·1	− 27·5	11	1920 May 14	12
25 10 23 45	+42·0	+141·0	4	1919 July 21	
25 10 29 38	+64·1	− 27·5	6	1920 June 24	
25 18 21 45	+64·1	− 27·5	10	1920 June 24	
25 21 17 10	+43·0	+ 15·0	9	1920 June 21	12
26 7 30 34	−18·5	− 10·0	9		11
27					15
28					12
29					8
30 4 15 20	+53·5	−159·0	*6	1919 July 31	
30 4 24 20	+53·5	−159·0	5	1920 June 30	13
1920 *July*.					
1 19 57 31	+36·1	+137·3	4	1920 May 28	28
2 18 41 5	− 7·0	+153·0	*40†	1918 Dec. 25	
2 21 36 45	− 3·5	+128·5	*44	1919 Aug. 29	29
3 14 19 0	+36·1	+137·3	6	1920 July 1	
3 16 34 36	+15·0	− 94·5	*14		11
4 0 11 35	− 2·0	− 14·0	27		
[illegible]	[illegible]	[illegible]	7		

25	11	39	55	+33·5	+ 46·5	10	1917 Nov. 24	9
26	12	21	40	−18·0	−173·0	*33	1918 Feb. 3	9
27	5	49	12	+ 5·0	+110·0	26†	1920 Feb. 26	10
28	18	25	0	+36·1	+137·3	3	1919 Sept. 12	4
29	12	23	0	+25·0	+119·5	6	1918 Dec. 18	
29	19	12	30	+43·0	+ 15·0	14		19
30	10	11	10	+43·0	+ 15·0	11	1920 May 29	
30	20	51	20	+32·2	−110·1	16†	1918 Feb. 12	13
31								7
				1920 *June.*				
1								6
2	22	1	40	+21·0	−106·5	*32	1919 Sept. 15	
2	23	55	24	+23·0	+135·0	16		6
3								9
4	4	44	57	+44·6	+ 13·3	4	1918 Nov. 6	
4	4	49	7	+44·6	+ 13·3	5	1920 June 4	
4	15	29	15	+32·2	−110·1	11	1920 May 30	
4	15	36	40	+32·2	−110·1	5	1920 June 4	9
5	4	21	30	+24·0	+120·0	*75	1919 Sept. 8	102
6								46
7	22	0	20	−21·0	− 67·0	9	1919 Aug. 9	21
8	16	12	50	+44·5	+ 11·5	9	1919 Sept. 20	
8	17	17	10	+44·5	+ 11·5	4	1920 June 8	
8	18	29	35	+44·5	+ 11·5	7	1920 June 8	17
9	3	9	37	+54·8	+143·7	11		
9	11	30	35	− 3·5	+129·0	*56	1919 Aug. 29	23
10	2	29	30	+11·0	+127·0	*20		
10	17	53	43	+46·5	+151·5	22		20
11								6
12	1	20	0	+37·0	+ 20·5	13	1919 June 3	
12	15	26	10	−23·8	+172·5	12		13
13								10
14	13	6	14	+40·0	+ 76·0	5	1919 July 24	
14	13	8	10	+40·0	+ 76·0	14	1920 June 14	8
15	3	3	0	+24·5	+143·5	*14	1919 Sept. 11	

5								13
6	3	0	40	−15·7	+167·3	33	1919 Aug. 31	20
7	18	41	24	+60·2	−138·0	35		
7	19	55	40	−20·0	+111·0	10		22
8	4	39	55	− 5·6	+102·0	13	1918 Feb. 13	19
9								16
10	15	58	30	+25·0	+ 68·0	17		22
11	1	30	35	+52·7	−167·0	*15		
11	17	27	20	+40·0	+ 14·0	12	1919 Oct. 25	12
12	1	34	28	+34·6	+140·7	4	1919 Aug. 15	21
13	8	11	12	+34·6	+140·7	4	1920 July 12	14
14								11
15								17
16	17	14	15	+ 6·0	− 84·0	*23		9
17								8
18	22	27	35	+46·0	+152·5	*9	1913 Jan. 19	7
19								6
20	0	21	35	−50·0	−127·0	20		
20	3	59	30	+34·0	+ 14·0	7		
20	12	18	30	+33·8	+140·5	13†		21
21	14	29	5	+34·4	+ 27·0	23		10
22								12
23								6
24								14
25								15
26	5	12	35	−32·7	− 73·7	24†		18
27								4
28								27
29								15
30	20	6	20	+45·0	+ 16·0	13	1916 Mar. 12	7
31								7
				1920 *August.*				
1								6
2								31
3	3	2	15	+ 6·5	+128·0	*39†	1920 Mar. 12	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

1920 *August*—contd.

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
3 19 57 10	−27·6	− 66·3	*55		22
4					13
5 19 1 44	+21·1	+121·7	17	1919 May 4	5
6					13
7					17
8					11
9					8
10 20 48 30	−40·9	+177·1	6	1917 Aug. 8	
10 21 53 49	+36·3	+ 26·3	7	1918 July 16	11
11					15
12 6 20 55	+25·0	− 46·0	15	1919 Jan. 8	7
13 2 2 45	−18·5	− 63·5	*31	1918 Aug. 17	8
14					8
15 6 59 8	+22·2	+ 93·2	17		
15 8 16 33	−13·0	+166·8	*56†	1919 Nov. 20	32
16 14 41 38	+34·0	+ 14·0	15	1920 July 20	7
17 7 42 50	+44·5	+140·0	8	1919 Mar. 12	17
18					16
19					20
20 16 15 28	−38·0	− 73·5	*57		23
21 21 19 18	+53·0	− 23·0	20		8
22					7
23					12
24					6
25 21 53 25	− 7·0	+148·0	29	1919 Oct. 21	6
26 22 59 54	+52·5	−170·0	*51		2
27 3 25 8	− 2·0	+133·0	6	1918 Jan. 21	19
28					15
29 10 49 8	−18·0	+170·1	13	1920 Jan. 29	11
30					8
31					15

1920 *September*—contd.

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
8 23 19 30	+43·8	+ 11·2	3	1920 Sept. 8	9
9 18 56 0	−15·0	+171·5	*52		17
10 22 3 0	−12·6	+150·0	7	1918 July 31	23
11 2 19 40	+43·8	+ 11·2	5	1920 Sept. 8	
11 3 50 25	+43·8	+ 11·2	10	1920 Sept. 11	
11 14 32 45	+43·8	+ 11·2	7	1920 Sept. 11	15
12 16 31 24	+43·8	+ 11·2	11	1920 Sept. 11	22
13					10
14 2 8 45	+41·0	+ 21·5	19		15
15					13
16 4 17 0	+43·8	+ 11·2	12	1920 Sept. 12	
16 15 8 0	+42·3	+140·0	*21	1915 Mar. 17	
16 18 28 50	+43·8	+ 11·2	6	1920 Sept. 16	14
17 23 50 36	+32·5	− 42·0	20		13
18					8
19					7
20 14 38 50	−20·6	+168·8	*76		
20 17 28 15	−20·6	+168·8	13	1920 Sept. 20	
20 20 25 57	+40·0	+144·5	*17	1917 Apr. 21	
20 23 35 8	+45·5	+ 94·0	22		7
21 2 34 18	−18·0	+167·0	*21	1920 Feb. 27	
21 17 42 6	+45·3	+153·5	*43		17
22					11
23 5 32 35	+49·0	+156·0	*30		
23 19 37 0	+49·0	+156·0	22	1920 Sept. 23	14
24 21 54 50	+ 6·0	− 83·0	*32		24
25					8
26					18
27 5 25 45	+27·0	−109·5	26	1918 May 23	
27 5 29 36	+43·7	+144·4	4		26
28 15 17 20	+38·0	+ 29·5	20		7

1	2	45	50	− 3·0	− 88·0	8	1918 Feb. 3	
1	10	33	0	+35·5	− 6·4	15		13
2								6
3								31
4	14	8	55	−51·0	+ 3·0	*40		18
5								8
6	4	40	30	+36·0	+139·0	3	1919 Jan. 24	
6	6	29	10	+35·0	+ 24·0	4	1918 Sept. 30	
6	14	5	24	+43·8	+ 11·2	27	1920 Mar. 8	
6	23	16	50	+48·4	+150·4	*16		19
7	5	55	40	+43·8	+ 11·2	*48	1920 Sept. 6	
7	6	34	10	+43·8	+ 11·2	3	1920 Sept. 7	
7	8	11	0	+43·8	+ 11·2	13	1920 Sept. 7	
7	8	28	10	+43·8	+ 11·2	5	1920 Sept. 7	
7	8	48	0	+43·8	+ 11·2	5	1920 Sept. 7	
7	8	51	50	+43·8	+ 11·2	2	1920 Sept. 7	
7	9	1	5	+43·8	+ 11·2	4	1920 Sept. 7	
7	9	53	20	+43·8	+ 11·2	3	1920 Sept. 7	
7	10	14	50	+43·8	+ 11·2	9	1920 Sept. 7	
7	11	26	25	+43·8	+ 11·2	9	1920 Sept. 7	
7	13	32	20	+43·8	+ 11·2	12	1920 Sept. 7	
7	16	14	5	+43·8	+ 11·2	3	1920 Sept. 7	
7	17	29	10	+43·8	+ 11·2	2	1920 Sept. 7	
7	18	4	30	+43·8	+ 11·2	2	1920 Sept. 7	
7	18	5	0	+43·8	+ 11·2	3	1920 Sept. 7	
7	18	42	43	+43·8	+ 11·2	12	1920 Sept. 7	
7	23	35	25	+43·8	+ 11·2	4	1920 Sept. 7	
7	21	54	25	+36·0	+139·0	4	1920 Sept. 6	29
8	0	54	50	+43·8	+ 11·2	4	1920 Sept. 7	
8	1	19	14	+43·8	+ 11·2	10	1920 Sept. 8	
8	1	45	35	−22·0	180·0	*65	1917 May 24	
8	3	33	10	+43·8	+ 11·2	2	1920 Sept. 8	
8	9	41	24	+43·8	+ 11·2	14	1920 Sept. 8	
8	13	50	50	+43·8	+ 11·2	3	1920 Sept. 8	
8	17	50	50	+43·8	+ 11·2	5	1920 Sept. 8	
8	18	43	50	+43·8	+ 11·2	10	1920 Sept. 8	

1920 *October.*

1	18	49	40	+17·0	− 99·0	24		9
2								20
3								12
4								11
5	19	4	25	+36·5	−122·0	7		11
6								6
7	20	54	0	−12·0	− 69·0	*37	1920 Feb. 28	15
8	16	50	45	+16·0	− 90·0	*28		31
9								12
10	19	43	0	−13·0	− 60·0	11		13
11								8
12	6	54	40	+35·7	+ 81·0	32		29
13	23	11	55	+34·7	+ 19·3	14		13
14								6
15	11	9	50	+43·8	+ 11·2	5	1920 Sept. 16	
15	14	7	37	−75·5	+150·0	17		10
16	11	36	30	+50·4	− 31·6	10		4
17								2
18	8	11	30	+46·0	+149·0	*67	1919 Feb. 12	26
19	18	24	18	+44·5	+140·0	3	1920 Aug. 17	9
20	10	2	16	+24·0	+120·0	*44	1920 June 16	
20	19	16	0	+24·0	+120·0	*19	1920 Oct. 20	13
21	18	57	50	+40·0	+ 20·0	28	1919 Jan. 5	8
22	10	51	47	− 7·0	+145·0	18	1918 Sept. 30	
22	12	9	50	−21·5	− 72·0	*49		
22	21	35	3	+46·0	+ 9·0	4	1920 Apr. 1	15
23								13
24	1	38	25	−16·2	+165·4	*25		12
25								12
26	0	3	2	+40·0	+ 20·0	5	1920 Oct. 21	
26	19	4	20	+19·4	−122·2	8		8
27	11	44	21	+19·0	− 70·0	13	1920 Jan. 26	8
28	7	23	40	+51·0	−179·5	*31	1918 Sept. 30	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
	1920 *October*—contd.				
28 12 50 6	−27·0	− 74·4	*56		20
29					9
30					5
31					5
	1920 *November*.				
1 16 53 36	− 8·0	+146·5	13	1918 July 6	11
2					9
3 15 35 36	+ 6·5	+126·0	18	1920 May 7	7
4 2 11 30	+19·0	− 70·0	16	1920 Oct. 27	6
5					15
6 10 44 30	+19·0	− 70·0	13	1920 Nov. 4	
6 21 11 12	−13·5	+162·0	12		8
7					2
8 17 37 25	+35·0	+143·0	14	1919 Aug. 3	12
9					7
10					9
11					8
12 5 41 48	0·0	− 28·2	40		12
13 10 30 34	+43·8	+ 11·2	5	1920 Sept. 16	16
14					12
15 9 20 43	+34·5	+ 25·0	11	1918 July 1	18
16 5 52 30	+24·5	+126·5	7	1918 Feb. 13	
16 8 30 52	+71·8	−127·0	*45		7
17					16
18					17
19					11
20					15
21 20 57 40	+34·5	+ 25·0	3	1920 Nov. 15	11

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
	1920 *December*—contd.				
19 20 10 45	+38·3	+141·0	*31		13
20					11
21					18
22					10
23					7
24					11
25 11 33 8	+35·79	+105·74	*62	1920 Dec. 16	7
26					19
27 9 20 20	+33·2	+138·0	5	1919 May 31	
27 16 19 0	+43·8	+ 11·2	5	1920 Nov. 13	12
28 3 16 30	+35·5	+104·0	18		
28 5 27 12	+38·5	+142·5	8	1918 Dec. 22	9
29					10
30					15
31					8
	1921 *January*.				
1 10 59 13	+45·0	+ 16·0	4	1920 July 30	13
2 7 6 20	+43·5	+153·0	*40	1915 June 27	9
3 20 54 36	−22·0	+174·0	12	1918 June 5	21
4					12
5					19
6 11 59 56	− 7·0	+148·0	28	1920 Aug. 25	
6 23 9 45	+38·0	+107·0	18		11
7 1 0 36	−30·2	−177·7	*29	1918 Aug. 5	
7 2 51 11	−53·0	+140·0	37		
7 9 42 25	+38·0	+107·0	20	1921 Jan. 6	15
8 6 35 27	+14·5	− 94·0	12		11
9 12 55 0	−14·0	− 74·5	*36	1916 Oct. 3	

24	11	51	0	−14·3	− 64·2	11†		12
25	8	38	36	+40·0	+ 20·0	15	1920 Oct. 26	4
26	8	51	0	+40·0	+ 20·0	37	1920 Nov. 25	
26	11	38	20	+41·5	− 7·0	15	1919 Sept. 10	17
27	16	26	20	+37·5	+ 27·5	10	1920 Apr. 2	8
28	8	1	40	+36·5	+ 19·7	5	1918 July 18	
28	11	29	55	+50·0	−128·0	12	1919 July 10	10
29	8	2	45	+59·0	−149·0	*23		
29	15	48	0	+40·0	+ 20·0	21	1920 Nov. 26	8
30								16

1920 *December.*

1								13
2	23	40	5	+36·5	+140·5	5		17
3								16
4	5	51	30	−39·0	+ 23·5	*23		
4	23	8	33	+25·0	+119·5	18	1920 May 29	15
5	10	1	0	0·0	− 18·8	32		
5	21	57	24	− 7·2	+150·0	10	1920 Jan. 14	8
6	1	28	0	+25·0	+119·5	13	1920 Dec. 4	17
7	15	14	30	−13·0	+166·8	17	1920 Aug. 15	9
8	3	55	20	+36·7	+ 21·0	12	1919 Mar. 6	19
9								17
10	4	25	35	−39·0	− 74·5	*57		
10	18	35	18	+36·7	+ 21·0	10	1920 Dec. 8	16
11	21	22	18	+14·5	− 91·0	*31	1920 Mar. 23	11
12								11
13	3	42	30	− 7·0	+157·0	21		6
14								6
15								6
16	12	5	43	+35·79	+105·74	*78†		
16	21	10	0	−13·0	+166·8	15	1920 Dec. 7	27
17	3	38	28	+22·0	+123·5	6	1918 Apr. 1	
17	18	59	49	−33·0	− 68·6	*37		17
18	2	1	20	+40·0	+ 20·0	24	1920 Nov. 29	
18	10	3	40	+ 0·5	+126·5	13†		20

10								13
11								6
12	14	53	10	+33·5	+131·9	4		9
13								21
14								23
15								12
16	23	55	48	+38·8	+ 32·9	12	1920 Feb. 26	14
17								11
18								7
19	14	57	18	+45·0	+152·1	*26	1918 Sept. 14	14
20	2	2	24	+ 7·0	− 82·5	18	1919 Sept. 27	12
21								8
22								16
23	16	18	57	+ 2·0	− 20·5	5		14
24	11	16	36	−12·2	+118·0	6		9
25	10	27	55	+41·9	+142·1	5		9
26	17	55	8	+ 4·0	+ 97·0	4	1916 July 27	9
27	11	30	9	+36·0	+ 28·0	13	1919 Aug. 24	20
28								7
29								7
30	18	58	38	− 0·5	− 93·0	5		15
31								7

1921 *February.*

1								12
2								10
3								16
4	8	22	35	+16·5	− 89·5	*72		14
5								19
6	4	27	24	+48·6	+159·4	*33	1914 Feb. 7	4
7								6
8								12
9								7
10	19	42	16	− 3·0	+177·5	23		
10	23	53	35	+17·6	+148·1	38		12
11	22	39	36	+ 9·5	− 84·0	9	1918 June 22	2

Catalogue of Earthquakes, 1918–1924—*contd.*

	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1921 *February*—contd.			
d. h. m. s.	°	°			
12					12
13 20 57 6	−39·0	− 17·0	7	1919 Apr. 16	14
14 1 0 47	+ 5·0	+132·8	32		
14 3 0 30	+36·0	+139·0	11	1920 Sept. 7	15
15					10
16					8
17					13
18					12
19 14 33 44	− 1·4	+133·0	43		
19 18 14 30	− 3·0	+139·0	59		23
20					12
21 2 0 22	+25·0	+ 70·7	13		
21 11 40 0	+46·0	−130·0	11	1920 Jan. 2	
21 15 56 30	+52·0	−125·0	*31		
21 19 23 24	+46·0	−130·0	17	1921 Feb. 21	18
22					10
23					10
24					11
25					6
26					5
27 18 23 28	−19·0	−173·0	*79		5
28					13
		1921 *March*.			
1 6 36 52	0·0	+135·0	15	1919 Nov. 23	10
2					8
3 3 2 15	+38·0	+141·5	*49		
3 8 20 40	− 6·5	+107·5	*36		6
4 12 50 58	+29·0	+139·0	10†		10
5 6 24 8	+ 7·0	+ 94·0	28	1915 Aug. 12	9

	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1921 *April*—contd.			
d. h. m. s.	°	°			
4					4
5 17 40 16	+44·0	+ 13·0	6	1918 Feb. 8	15
6					15
7					12
8					6
9					4
10 13 40 10	+53·2	−133·7	*35		7
11					14
12 7 29 10	+53·2	−133·7	*23	1921 Apr. 10	
12 9 36 0	+37·2	+101·4	19		8
13 4 54 5	+37·5	+ 32·5	7	1914 Oct. 3	3
14					11
15 21 6 10	−33·3	−173·7	*11†		1
16					5
17					13
18 17 59 0	+32·7	+131·9	8		6
19					10
20 16 4 10	+35·2	+ 33·3	16		
20 18 46 3	+32·5	− 48·0	20		10
21					12
22 6 21 36	−30·2	−177·7	*37	1921 Mar. 24	
22 16 3 45	+43·0	− 17·0	20		
22 20 47 0	−30·2	−177·7	10	1921 Apr. 22	8
23					13
24					8
25 17 33 43	−22·0	180·0	38†	1920 Sept. 8	8
26					6
27 2 5 16	− 0·4	− 20·0	6	1918 June 3	20
28					18
29					3
30					7

8								9
9								9
10	20	5	8	−11·0	+160·0	16		4
11								12
12	10	30	24	+ 7·0	− 82·5	21	1921 Jan. 20	9
13								10
14								4
15	4	31	40	+33·2	+138·0	4	1920 Dec. 27	23
16	11	36	40	−13·0	+138·0	11		6
17								12
18								7
19	8	19	45	+24·0	+116·5	*26	1919 Oct. 31	7
20								11
21	4	6	15	+ 3·2	− 82·7	*18		
21	6	41	10	+ 3·2	− 82·7	5	1921 Mar. 21	2
22	11	54	27	−38·8	−146·0	12		2
23	22	44	50	− 5·5	+130·0	21†	1920 May 10	10
24	1	26	0	− 5·5	+130·0	19†	1921 Mar. 23	
24	9	17	7	−30·2	−177·7	*30	1921 Jan. 7	
24	14	41	40	+50·5	+159·0	*62		18
25	0	32	50	+33·6	−111·4	25		8
26								14
27								2
28	7	49	20	+14·5	− 86·0	*75	1919 June 29	13
29	22	11	45	+46·5	+151·5	*41	1920 June 10	11
30	10	26	30	+22·2	+ 93·2	21	1920 Aug. 15	
30	15	2	10	− 7·6	+128·3	51†		
30	15	5	30	+41·0	+ 23·0	33		4
31								10
				1921 *April*				
1	4	6	40	+ 2·4	+ 98·8	*63		
1	12	0	24	−11·7	+166·3	*47	1920 May 20	11
2	9	36	45	+23·3	+122·0	*63	1919 Oct. 15	10
3								13

1	5	38	56	+18·5	−104·5	*58		28
2								10
3	8	23	12	+43·5	+ 7·5	5	1919 Nov. 28	
3	10	42	50	−15·0	−172·0	11		9
4	4	53	30	+45·0	+135·0	14	1919 May 16	
4	17	35	48	+48·0	+ 18·0	16		
4	21	12	25	−11·0	−176·0	11	1918 Aug. 1	7
5								13
6								8
7								5
8								6
9								12
10	4	55	50	+41·0	+ 24·6	25	1919 Oct. 9	16
11								20
12	3	40	14	− 6·5	+153·5	38†	1918 Jan. 4	4
13	11	53	10	+34·6	+140·7	5	1920 July 13	
13	12	41	45	+ 0·7	+117·9	8		
13	19	59	36	+ 0·7	+117·9	9	1921 May 13	
13	21	9	20	+ 0·7	+117·9	12	1921 May 13	27
14	11	17	45	+ 0·7	+117·9	*31	1921 May 13	
14	12	27	24	−29·2	−177·0	11	1919 Dec. 14	
14	20	18	3	−29·2	−177·0	*45	1921 May 14	
14	22	9	30	+20·0	−103·0	*30		12
15								11
16	15	12	36	−23·5	+178·0	19		16
17	23	14	45	+21·0	+127·0	*7	1919 May 16	
17	23	26	20	+21·0	+127·0	*21	1921 May 17	10
18								17
19								13
20	0	43	10	+35·0	+ 69·0	*48†	1920 Feb. 27	
20	13	22	0	− 2·0	+128·5	12†		
20	18	15	40	+43·8	+ 11·2	5	1920 Dec. 27	25
21	8	42	0	+12·5	+124·5	*52		
21	11	10	20	+35·0	− 16·0	13		
21	22	25	42	+48·0	+157·0	*54		
21	23	37	20	+12·5	+124·5	11	1921 May 21	27

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1921 *May*—contd.					
22 18 22 18	+18·5	− 68·0	9	1918 Oct. 25	
22 21 23 16	+37·0	+ 28·7	12	1920 May 1	
22 23 11 0	+36·1	+137·3	3	1920 July 3	10
23 4 13 18	+12·5	+124·5	*19	1921 May 21	34
24					22
25					18
26 5 4 27	+39·3	+ 21·0	7	1919 Dec. 22	14
27					13
28 19 18 56	+ 5·2	+129·4	21		
28 20 3 42	+48·0	−127·5	*28		3
29					6
30					14
31					12
1921 *June*.					
1 19 35 38	+54·0	+156·0	*11	1914 Mar. 18	16
2 7 6 20	−11·0	+ 97·0	*13		7
3					6
4					20
5					17
6 0 9 15	+ 6·0	− 83·0	3	1920 Sept. 24	3
7					11
8					7
9 10 34 50	+ 5·6	+126·3	5	1918 Feb. 27	7
10 1 10 30	+39·3	+ 21·0	6	1921 May 26	10
11					5
12					9
13					14
14 1 41 55	+48·0	+ 35·0	14		

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1921 *July*—contd.					
13 10 16 24	−34·0	− 8·0	*22		21
14			†		1
15 18 6 12	+ 2·1	+127·8	32†	1920 Jan. 26	16
16					4
17					9
18 17 3 0	+23·0	+121·7	21	1919 Dec. 20	10
19					10
20 5 25 35	+70·0	− 11·0	7	1919 Feb. 15	10
21 0 16 12	+13·0	+123·0	7	1919 Apr. 27	11
22					17
23					13
24 19 20 0	+39·0	+ 27·0	12	1918 June 19	19
25 1 40 35	+24·0	+123·0	*14	1920 Mar. 13	
25 19 27 14	+24·0	+123·0	*31	1921 July 25	26
26 10 37 6	+46·0	+152·5	*10	1920 July 18	9
27					7
28					6
29 0 28 50	−15·0	−172·0	27	1921 May 3	13
30					10
31 9 50 42	−15·7	+167·3	37	1920 July 6	12
1921 *August*.					
1					17
2 3 17 40	+39·0	+ 27·0	5	1921 July 24	14
3					7
4					4
5 1 26 36	−48·0	− 17·0	8		16
6					5
7					5

16	9	4	52	−65·0	0·0	7	1917 July 15	1
17	8	10	0	+30·0	−114·0	10		
17	10	19	30	+30·0	−114·0	8	1921 June 17	2
18								8
19								9
20								9
21								13
22	11	23	16	+43·0	+142·5	*13		7
23	10	34	18	+28·0	+130·0	7		
23	18	21	15	+28·0	+130·0	21	1921 June 23	18
24								6
25	2	5	36	+49·0	−124·0	20	1919 Oct. 10	
25	15	31	6	+37·5	+134·5	5		18
26	3	40	38	+39·3	+ 21·0	30	1921 June 10	8
27								3
28	13	58	48	−37·0	+175·0	*45		3
29	11	37	50	+43·0	+ 44·0	18		11
30	2	10	3	+61·5	− 33·5	24		10

1921 *July.*

1								9
2								7
3	5	2	40	−16·5	180·0	12	1919 Oct. 19	
3	14	52	50	+29·0	+130·0	*20		11
4	14	18	0	+25·0	+141·5	12†	1919 Apr. 27	
4	14	18	0	+29·0	+130·0	*34†	1921 July 3	5
5	17	8	10	+42·4	+ 11·1	12	1917 July 8	11
6								6
7	10	33	7	−47·0	− 78·0	*21		
7	10	45	50	−12·2	+164·7	8		13
8	10	48	48	+20·0	− 78·0	9		22
9								12
10								27
11								5
12								14

11	17	34	20	+41·0	+ 21·5	7	1921 Aug. 10	4
12								4
13	12	54	10	− 9·2	+123·5	16		2
14	13	15	18	+15·5	+ 39·0	41		11
15	14	10	45	−18·0	+167·0	*9	1920 Sept. 21	12
16	5	18	36	+36·0	+141·0	11	1919 July 9	15
17								17
18								8
19	8	33	35	+34·5	− 77·5	9		5
20								5
21	1	9	16	+26·0	− 50·0	9		11
22	4	5	0	+36·0	+141·0	*23	1921 Aug. 16	16
23	5	11	50	+56·8	− 33·6	15	1920 Feb. 7	
23	20	17	16	+67·5	− 18·6	56	1913 July 26	21
24								20
25								17
26								7
27								13
28								24
29	19	4	10	+40·0	− 92·0	7		13
30								8
31	21	3	0	+40·0	+136·5	16	1921 Jan. 9	6

1921 *September.*

1								21
2	9	41	20	+42·4	+ 21·4	7		8
3	8	57	50	+32·5	+143·0	*22		6
4								4
5	17	54	53	+22·0	+123·5	6	1920 Dec. 17	
5	19	56	54	+47·3	+151·5	*60		12
6								14
7	22	28	50	+33·8	+140·5	3	1920 July 20	7
8	19	23	45	+33·6	−116·4	16	1919 Oct. 1	5
9	12	22	44	+42·5	+ 3·0	5		5
10								8

Catalogue of Earthquakes, 1918–1924—*contd.*

1921 *September*—contd.

d.	h.	m.	s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
11	4	1	30	−11·5	+112·0	*83		13
12	0	24	52	+45·0	+ 11·5	6	1920 Feb. 28	
12	5	9	48	+18·0	+ 97·0	9	1919 Sept. 8	
12	23	23	42	+56·0	+153·0	*6		11
13	2	36	40	−55·0	− 27·5	*59		
13	8	59	50	+38·0	+ 20·5	33		14
14	3	27	35	+38·0	+ 20·5	20	1921 Sept. 13	16
15								13
16								12
17	22	49	24	+36·1	+137·3	3	1921 May 22	9
18								8
19	4	6	45	+52·5	−170·0	*33	1920 Aug. 26	
19	23	16	30	−19·0	+179·0	*51		6
20	18	51	30	−11·0	−176·0	14	1921 May 4	
20	20	21	15	+ 1·5	+110·0	8†	1918 Jan. 16	22
21	11	1	26	+15·5	+ 39·0	39	1921 Aug. 14	10
22	6	32	57	− 4·0	+101·0	9	1919 Oct. 12	
22	9	14	0	− 6·5	+126·0	6	1920 Nov. 3.	5
23								15
24								10
25								5
26	9	25	55	+39·3	+ 33·2	28		
26	21	14	42	+29·0	+137·0	7		9
27	16	20	54	+39·5	+145·0	*29		16
28	17	8	50	+11·0	+127·0	6	1920 June 10	4
29	13	9	20	+49·5	+152·5	*30		8
30								12

1921 *October*.

1921 *November*.

d.	h.	m.	s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1								8
2	3	38	0	+17·0	− 99·0	18	1920 Oct. 1	
2	7	56	40	−12·0	− 78·5	*29		30
3	17	13	36	+43·0	− 6·5	6		14
4								2
5								16
6	16	54	50	−18·0	−173·0	18	1920 May 26	12
7	15	59	40	+ 6·5	+126·0	*53	1921 Sept. 22	12
8								8
9								8
10								10
11	1	18	45	+34·2	+ 77·5	9	1917 May 9	
11	14	30	12	+51·0	−179·5	10	1920 Oct. 28	
11	18	36	6	+ 8·0	+128·0	*77	1919 Mar. 21	7
12								11
13	8	40	45	+10·5	− 71·0	25		
13	13	51	15	+20·5	+141·5	23		12
14	6	51	40	−18·0	+173·5	14	1921 Oct. 18	12
15	4	50	3	+35·3	+130·8	6		
15	20	36	30	+36·5	+ 70·5	*70†		19
16	13	53	2	+35·3	+130·8	4	1921 Nov. 15	
16	14	38	50	+ 3·0	+122·0	10	1920 May 19	10
17	7	51	25	+11·0	+127·0	13	1921 Sept. 28	
17	22	12	30	+36·5	−118·0	3	1915 Oct. 3	7
18	2	33	36	+11·0	+127·0	7	1921 Nov. 17	14
19								8
20								14
21								7
22	20	7	30	+15·0	+111·0	5	1917 Feb. 5	9
23								8

2	18 25 8	+55·0	+ 38·0	4		3
3						13
4	5 23 0	+34·5	+ 25·0	13	1920 Nov. 21	11
5	1 42 20	+50·0	−175·0	*10	1919 Jan. 27	
5	4 16 32	+40·3	+139·5	6	1920 Feb. 7	6
6	15 59 36	+43·0	+170·0	*16		11
7						20
8						4
9	0 12 54	−15·0	+ 94·0	25		19
10	2 6 30	− 5·0	+135·0	*45†		
10	8 30 20	+37·5	+134·5	3	1921 June 25	5
11						9
12	7 52 12	+46·7	+145·8	*34	1920 Feb. 22	8
13						11
14	16 43 45	+30·5	+ 91·0	43		5
15	4 58 5	−14·0	+166·5	*66		15
16						7
17						13
18	0 27 50	−18·0	+173·5	16	1920 Jan. 1	
18	11 57 5	−18·0	+173·5	7	1921 Oct. 18	2
19						10
20	6 3 15	−18·0	− 66·0	*65		
20	10 35 20	− 0·5	+152·0	19	1918 May 20	5
21	2 6 10	+41·0	+ 21·5	21	1921 Aug. 11	
21	22 20 54	+46·5	− 28·3	9	1918 Nov. 25	2
22	21 18 50	+34·0	+ 4·0	4		8
23	12 33 36	+37·5	− 9·0	5		8
24						11
25	0 47 30	−27·0	− 72·0	9	1919 Feb. 20	
25	15 4 25	+37·0	+ 20·5	14	1920 June 12	
25	15 45 25	+ 7·0	− 82·5	11	1921 Mar. 12	10
26	7 5 35	+25·0	+ 68·0	10	1920 July 10	
26	23 2 40	+25·0	+ 68·0	7	1921 Oct. 26	13
27						4
28						6
29						8
30						8
31						13

26						7
27						15
28						16
29	2 43 36	+28·0	+130·0	7	1921 June 23	
29	4 15 45	+36·0	+141·0	5	1921 Aug. 22	
29	12 4 4	+43·9	+ 9·5	4	1917 Apr. 26	
29	22 46 0	−18·0	−173·0	10	1921 Nov. 6	12
30						7
			1921 December.			
1	10 49 32	+30·0	+119·5	31		
1	17 53 10	+24·0	+124·0	10	1919 Dec. 16	16
2	20 43 8	−20·6	+168·8	7	1920 Sept. 20	13
3						12
4						6
5						2
6	13 26 16	+40·0	+ 45·5	14		5
7	17 27 20	+ 2·1	+127·8	*28	1921 July 15	
7	18 40 40	+ 2·1	+127·8	4	1921 Dec. 7	9
8	12 31 24	+36·0	+139·0	*56	1921 Feb. 14	26
9						14
10						8
11						11
12	11 2 10	+40·3	+139·5	5	1921 Oct. 5	11
13	6 28 42	+43·9	+ 9·5	3	1921 Nov. 29	8
14						5
15						9
16	2 37 15	+14·5	+145·5	8	1919 Jan. 11	12
17						8
18	10 16 24	− 2·0	− 14·0	9	1920 July 4	
18	15 29 24	− 2·5	− 71·0	*82†		
18	15 43 20	+19·0	+144·0	12	1919 Aug. 27	28
19						14
20	8 4 20	+37·2	+139·0	9	1919 Apr. 15	12
21	10 14 45	+ 2·0	− 20·5	7	1921 Jan. 23	6
22	20 42 50	+19·3	− 62·5	7	1919 Aug. 30	15
23						7

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1921 *December*—contd.					
	°	°			
24					3
25					4
26					24
27					8
28					16
29					9
30					5
31					7
1922 *January*.					
1 12 3 45	− 3·5	+146·5	10		
1 19 46 15	−19·0	−177·0	51	1919 Apr. 23	15
2					10
3 20 56 42	−15·0	+178·0	6		15
4					12
5					13
6 14 10 36	−19·0	− 76·0	*70		
6 19 20 38	−19·0	− 76·0	*16	1922 Jan. 6	19
7 9 20 12	+ 6·7	+128·3	11		13
8 1 57 0	+52·5	+158·0	14		
8 23 49 0	+33·0	+142·0	5		7
9 5 9 22	+24·0	− 46·0	66		6
10 13 41 12	+24·0	+123·0	26	1921 July 25	10
11					4
12 10 42 0	+40·0	+ 20·0	16	1920 Dec. 18	6
13					2
14					19
15					6
16					16
17 2 50 24	2·0	− 72·0	*91†		7

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1922 *February*—contd.					
	°	°			
14 12 27 45	+26·0	−100·0	4		
14 12 45 12	−13·5	+ 68·5	*47		10
15 1 16 6	+37·0	+141·0	5		
15 8 10 0	−48·0	+170·0	23		19
16 2 51 0	+46·5	− 28·3	21	1921 Oct. 21	
16 3 14 48	+13·0	− 85·4	*52	1919 Dec. 5	9
17					8
18					11
19 21 52 34	+32·5	− 31·5	25	1913 Dec. 25	13
20 7 43 50	−17·0	−168·0	*18	1914 Dec. 20	9
21					2
22 17 18 40	+28·0	+127·0	5		7
23					17
24 13 27 20	+40·5	+ 22·5	5		11
25					4
26 8 56 40	+44·0	+145·0	8		15
27 20 39 50	+10·0	+123·0	9		6
28					21
1922 *March*.					
1					13
2 14 49 27	+43·0	+ 44·0	12	1921 June 29	12
3					4
4 13 7 34	+52·5	+157·5	*72†		16
5					10
6 21 20 30	+52·5	+157·5	6†	1922 Mar. 4	1
7 16 54 50	−23·3	+150·6	7	1918 June 6	19
8 17 33 45	+34·5	+ 25·0	25	1921 Oct. 4	7
9					5
10 11 20 55	+33·0	−121·5	*43	1920 June 22	

19 21 58 50	− 7·0	+140·0	44	1917 July 27	14
20 6 50 54	− 6·5	+166·5	8		18
21					7
22 3 24 0	−19·0	−177·0	61	1922 Jan. 1	
22 20 44 20	−19·0	−177·0	40	1922 Jan. 22	
22 22 5 20	+37·5	+140·0	*20		24
23 23 31 50	+37·2	+139·0	4	1921 Dec. 20	15
24 13 3 6	+51·0	+141·0	7		8
25					5
26 9 19 12	+43·0	−125·0	5	1919 Aug. 24	
26 9 31 12	+43·0	−125·0	27	1922 Jan. 26	5
27					8
28					15
29					9
30					10
31 13 17 18	+41·1	−126·6	*106	1918 July 15	10

1922 *February.*

1					4
2 2 51 30	−49·0	−132·0	10		9
3					4
4					7
5 3 39 16	− 5·5	+119·0	14†		
5 22 19 28	+36·0	+134·0	4	1919 July 27	24
6					7
7					7
8					3
9 14 53 36	+33·2	+138·0	6	1921 Mar. 15	
9 23 48 30	+49·0	+144·0	11	1918 Mar. 23	10
10 13 37 0	+38·5	+142·5	5	1920 Dec. 28	5
11					10
12					9
13					11
14 1 6 45	+38·0	+136·0	5	1920 May 12	
14 12 8 30	+65·5	− 31·5	11		
14 12 23 24	+65·5	− 31·5	*23	1922 Jan. 14	

[illegible]	[illegible]	[illegible]	[illegible]	1921 Apr. [illegible]	[illegible]
11					16
12 16 51 45	−38·0	− 73·5	*49	1920 Aug. 20	15
13					17
14					6
15 3 27 42	+25·0	+ 2·0	15		
15 5 12 35	+39·0	+ 22·0	11		11
16 14 56 50	+ 6·0	+ 37·0	6	1919 June 30	
16 18 31 18	+35·0	+143·0	10	1920 Nov. 8	
16 23 11 20	+36·5	−122·0	6	1920 Oct. 5	15
17					19
18 8 58 0	+37·0	+138·5	4	1920 Feb. 19	10
19					6
20					10
21 16 56 12	+33·0	+ 50·0	12		9
22 22 29 25	+37·5	− 90·0	7		3
23					6
24 12 21 50	+45·0	+ 22·0	*41		2
25					10
26 13 25 32	−41·0	−135·0	14		12
27					5
28 3 57 50	−21·0	− 67·0	*64†	1920 June 7	3
29					22
30					7
31					21

1922 *April.*

1					13
2 17 0 45	+11·0	−108·0	17	1919 Nov. 14	
2 19 17 42	+53·3	−164·5	*59		16
3 19 28 40	+20·0	− 94·0	14		14
4					4
5 9 59 15	− 2·0	+137·0	61	1919 July 7	18
6 3 13 0	−14·0	− 77·0	*31		
6 8 0 45	−14·0	− 77·0	*27	1922 Apr. 6	9
7 6 38 0	+43·8	+ 11·2	5	1921 May 20	
7 15 58 18	+23·5	+119·0	*22		8

Catalogue of Earthquakes, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
				1922 *April*—contd.	
	°	°			
8 3 32 42	− 4·6	+101·6	*24		
8 20 42 12	+72·0	− 8·5	*70		19
9					8
10 3 9 36	+24·0	+123·0	4	1922 Jan. 10	
10 3 54 12	−15·0	+155·0	15		
10 13 57 25	+35·5	+141·0	5		17
11 0 18 20	−18·0	+167·0	42	1921 Aug. 15	
11 4 35 10	+40·5	+ 19·2	35		
11 15 43 30	−14·0	+166·5	11	1921 Oct. 15	19
12 8 8 25	+39·5	+145·0	8	1921 Sept. 27	11
13 6 7 12	+10·0	+127·5	5	1913 Apr. 28	
13 15 12 10	+60·0	−110·0	15		12
14					2
15					11
16 13 7 6	− 3·0	+ 24·0	36		8
17					14
18					10
19					7
20 5 48 18	+15·5	−101·2	16		
20 10 22 10	+36·0	+ 21·5	7	1917 Apr. 27	11
21					4
22					11
23 5 4 44	+35·5	+142·5	5		
23 21 30 36	+12·5	+124·5	21	1921 May 23	6
24					11
25 21 19 0	−13·0	+166·8	53	1920 Dec. 16	
25 21 39 30	−13·0	+166·8	14	1922 Apr. 25	
25 22 21 25	+46·0	+149·0	6	1920 Oct. 18	8
26 1 11 25	+35·0	+139·5	*36	1921 Oct. 2	

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
				1922 *May*—contd.	
	°	°			
24 21 17 25	+44·5	+ 11·5	10	1920 June 8	23
25 4 23 20	+44·5	+ 11·5	6	1922 May 24	9
26 8 34 18	+42·5	+ 7·5	9	1919 July 12	6
27					21
28 12 9 0	+37·2	+139·0	5	1922 Apr. 28	32
29					12
30					11
31					20
				1922 *June*.	
1 16 18 26	+19·5	+120·0	8		3
2 20 11 35	+ 8·0	+128·0	*57	1921 Nov. 11	8
3 4 14 0	+37·4	+ 30·5	8	1918 July 4	
3 4 56 30	+37·0	+141·0	*20	1922 Feb. 15	13
4 17 48 24	+38·0	+ 23·5	5	1918 Jan. 1	9
5 4 31 5	+35·0	+ 22·5	*37		
5 13 58 0	+42·0	+146·0	21		
5 15 42 20	+42·0	+146·0	4	1922 June 5	7
6					10
7 17 52 56	+37·0	+138·5	6	1922 Mar. 18	3
8 6 49 25	+43·0	+146·0	*7	1921 Aug. 9	
8 7 47 40	+43·0	+ 12·5	12	1919 Sept. 10	18
9 15 36 26	+43·0	+ 21·0	16		
9 16 13 20	+43·0	+ 21·0	15	1922 June 9	9
10					7
11					8
12 4 47 40	+24·0	−107·0	*65		
12 10 42 20	+19·5	−109·0	*40		22
13					11

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22
29					15
30					23
1922 *May.*					
1 10 51 10	+32·5	+143·0	14	1921 Sept. 3	24
2 11 10 45	+20·0	+ 98·0	*43		9
3 4 0 20	+51·2	−172·0	*12		14
4 9 12 45	+46·0	+154·0	*64		
4 21 26 15	+36·1	+137·3	6	1921 Sept. 17	10
5 0 18 30	+44·0	+152·0	*27		25
6 12 20 0	+47·3	+151·5	21	1921 Sept. 5	24
7					15
8					9
9 3 28 48	+36·5	+139·5	8		
9 7 25 10	+34·5	− 1·5	9		
9 13 50 15	− 8·1	+119·6	*31		17
10 9 20 6	− 6·0	+113·0	10		
10 16 31 54	+29·0	+139·0	6	1921 Mar. 4	6
11 0 44 32	−48·8	− 79·0	23		
11 6 45 25	+11·8	− 60·5	35		
11 9 14 55	−22·0	+170·0	36	1919 Sept. 1	3
12 18 39 20	−22·0	+170·0	*64	1922 May 11	13
13					11
14					17
15 20 21 16	+41·0	+144·0	*39	1919 June 23	9
16 8 6 45	+20·0	+121·0	*31		22
17					10
18					13
19					7
20					7
21 5 9 10	− 3·0	+128·0	7	1919 Feb. 17	
21 15 40 40	−34·0	− 73·0	17		16
22 17 33 18	+ 7·5	− 79·0	10	1918 Mar. 21	
22 18 4 40	+24·0	+120·0	*32	1920 Oct. 20	17
23					8

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
16 20 59 40	+30·0	−114·0	17	1921 June 17	9
17 2 34 0	+ 0·5	+130·0	8		16
18 12 14 25	+36·1	+137·3	3	1922 May 4	
18 12 17 20	+36·1	+137·3	9	1922 June 18	17
19 0 39 12	+40·5	+ 26·0	9	1917 Dec. 27	6
20 8 46 45	+32·0	+126·0	5		
20 9 43 6	+13·0	−120·0	8		8
21					10
22 23 15 15	+37·5	+ 19·7	9	1918 July 9	26
23					12
24 16 27 35	+ 6·3	+123·2	*11	1919 Sept. 26	12
25 18 41 16	+36·0	+141·0	4	1921 Nov. 29	13
26					7
27 14 29 55	+ 6·5	+126·0	*45	1921 Nov. 7	7
28					15
29 4 49 57	+31·5	+141·5	12		
29 10 30 20	+37·5	+ 19·7	8	1922 June 22	
29 17 10 15	+37·5	+ 19·7	6	1922 June 29	
29 20 54 50	+18·8	+120·0	5		9
30					13
1922 *July.*					
1 8 5 10	+37·5	+ 19·7	4	1922 June 29	12
2 8 26 30	+35·0	+142·0	7		
2 13 29 48	+23·3	+122·0	5	1921 Apr. 2	
2 13 35 48	+54·0	−160·5	*69		
2 20 6 48	+37·0	+ 20·5	5	1921 Oct. 25	
2 21 23 48	+30·0	− 90·0	6	1917 July 4	13
3 5 29 16	− 8·5	+ 67·0	*28		
3 8 21 45	+37·5	+ 19·7	5	1922 July 1	14
4					5
5 18 35 36	+54·0	−160·5	*12	1922 July 2	
5 20 20 0	+38·5	+144·5	*27	1917 June 14	7
6					8
7					18

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

	Lat. N.	Long. E.	Stns	Former Occasions.	Minor Ents.
		1922 *July*—contd.			
d. h. m. s.	°	°			
8					14
9					10
10 9 37 57	−15·2	− 61·0	*27†	1919 Sept. 16	7
11 14 13 0	+22·3	+143·2	17	1920 Jan. 12	1
12 5 11 46	+35·0	+ 24·0	9	1920 Sept. 6	10
13 1 22 46	−43·2	+148·5	9		
13 4 58 0	+ 6·3	+123·2	*38	1922 June 24	20
14 9 19 24	+38·0	+128·0	6		15
15					9
16					6
17					10
18					12
19 12 54 50	+25·5	+120·0	25		13
20					19
21					19
22 13 17 0	+55·0	+ 38·0	9	1921 Oct. 2	
22 16 26 40	+35·0	+ 22·5	33	1922 June 5	11
23					10
24					11
25					12
26 6 31 0	+50·0	− 50·0	6		16
27 3 0 54	+35·5	− 2·5	6		14
28 8 0 0	−28·5	− 71·5	11		
28 23 43 0	+32·5	− 42·0	11	1920 Sept. 17	19
29					21
30					7
31					4
		1922 *August.*			
					16

	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1922 *August*—contd.			
d. h. m. s.	°	°			
29 3 36 0	+38·0	+ 33·5	19		
29 17 0 48	+12·0	+123·1	*53	1915 Mar. 12	8
30 10 27 25	+ 3·0	+122·0	17	1921 Nov. 16	
30 22 40 42	+20·0	−114·0	16		13
31					16
		1922 *September.*			
1 19 16 0	+25·0	+121·5	*86†		34
2 17 22 42	− 3·0	+128·0	7	1922 May 21	19
3 3 11 0	+42·4	+ 21·4	15	1921 Sept. 2	26
4 17 4 8	− 9·0	− 66·0	*36†		
4 17 53 35	+24·0	+120·0	*29	1922 May 22	16
5 15 56 50	+41·0	+ 23·0	8	1921 Mar. 30	19
6 22 12 5	+24·0	+123·0	27	1922 Apr. 10	12
7					19
8 6 0 26	+24·0	− 46·0	7	1922 Jan. 9	
8 14 14 13	− 4·0	+ 68·0	*27		2
9 0 15 47	+17·5	−116·5	7		9
10 6 8 56	+30·6	+144·0	5	1919 Feb. 9	12
11 14 44 10	0·0	+122·4	*35		36
12					15
13					6
14 19 31 30	+25·0	+121·5	*68	1922 Sept. 1	11
15 7 13 30	+45·0	+135·0	6	1921 May 4	
15 16 11 10	+39·0	0·0	7		14
16 22 44 36	+25·0	+121·5	*52	1922 Sept. 14	15
17 7 22 36	+25·0	+121·5	*45	1922 Sept. 16	
17 7 53 6	+25·0	+121·5	*12	1922 Sept. 17	
17 9 59 18	+25·0	+121·5	*49	1922 Sept. 17	47
18 6 20 0	+25·0	+121·5	17	1922 Sept. 17	11

2	21	13	0	+43·8	+ 11·2	6	1922 Apr. 7	13
3	9	41	20	−18·5	+168·5	18†		12
4								13
5								17
6	0	56	15	+35·5	+142·0	*28		
6	6	1	20	−34·0	− 73·0	9	1922 May 21	3
7	12	22	20	+ 1·0	+147·0	20	1919 Apr. 22	15
8	3	49	6	+37·5	+ 23·0	34		16
9								18
10								15
11	8	19	36	+36·0	+ 28·0	*58	1921 Jan. 27	
11	13	38	0	+55·0	+167·0	*44		21
12								10
13	0	9	50	+36·0	+ 28·0	*74†	1922 Aug. 11	
13	12	46	0	+36·0	+ 28·0	36†	1922 Aug. 13	13
14	11	41	8	+52·0	+131·5	25†		17
15	14	53	12	+37·5	+ 23·0	17	1922 Aug. 8	6
16	9	41	30	+37·5	+ 23·0	7	1922 Aug. 15	
16	15	56	25	+52·5	+157·5	*61	1922 Mar. 6	25
17	15	3	36	+36·0	+ 28·0	7	1922 Aug. 13	13
18	5	12	15	+36·5	−122·0	15	1922 Mar. 16	
18	19	50	26	+13·0	− 85·4	*9	1922 Feb. 16	15
19	23	18	8	+37·5	+ 23·0	5	1922 Aug. 16	11
20	3	14	35	+22·0	+125·5	5	1913 Jan. 7	
20	5	0	36	+44·5	+ 11·5	7	1922 May 25	18
21	19	22	10	−12·0	− 69·0	12	1920 Oct. 7	10
22								13
23								22
24	17	12	30	+44·5	+ 11·5	4	1922 Aug. 20	
24	19	45	18	+35·5	+141·0	4	1922 Apr. 10	5
25	11	43	20	−13·5	+162·0	18	1920 Nov. 6	
25	11	47	24	+36·5	+ 1·5	24		
25	19	29	30	+50·0	+ 91·8	*51		7
26	2	19	25	− 7·0	+145·0	9	1920 Oct. 22	
26	6	25	16	− 9·0	+163·0	21		10
27								11
28								11

19	23	50	0	−18·0	− 73·0	8	1922 Sept. 19	23
20	12	32	8	+43·8	+ 11·2	6	1922 Aug. 2	17
21								20
22	18	13	45	+34·5	+ 25·0	8	1922 Mar. 8	
22	21	25	30	+27·0	− 42·0	10†		10
23	0	53	40	+40·5	+ 4·0	11		
23	6	37	10	+36·5	+140·5	6	1920 Dec. 2	7
24	12	16	0	+75·0	+100·0	14		13
25								14
26								11
27								5
28	22	1	5	+39·2	+120·5	17		10
29	18	44	35	+42·5	+ 89·3	23		
29	21	29	0	+15·5	−101·2	*23	1922 Apr. 20	15
30	23	35	6	+32·2	−110·1	8	1920 June 4	17
				1922 *October*.				
1	17	26	8	+ 3·0	+ 89·0	4		4
2								6
3								21
4								18
5	5	13	36	+ 2·1	+127·8	21	1921 Dec. 7	16
6	5	28	20	+62·0	−155·0	20		7
7								27
8								17
9								11
10	22	5	48	+24·0	+121·0	6	1919 Aug. 28	9
11	6	44	0	+41·5	+ 9·0	9		
11	14	49	45	−15·3	− 73·0	*77†		14
12								14
13								7
14	0	14	50	+19·0	+120·5	12		
14	3	56	25	+25·0	+121·5	18	1922 Sept. 18	
14	7	39	5	+25·0	+121·5	7	1922 Oct. 14	
14	23	46	45	+25·0	+121·5	*61	1922 Oct. 14	16
15								17

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

1922 *October*—contd.

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	°	°			
16 16 1 25	+39·5	+ 91·5	45		18
17 6 37 54	+12·0	+ 95·0	*34†	1918 Dec. 16	
17 9 56 0	+12·0	+ 95·0	8	1922 Oct. 17	22
18					7
19					8
20 20 22 48	+37·0	− 10·0	15		12
21					10
22					11
23					15
24 21 21 0	+47·3	+151·5	*83†	1922 May 6	9
25					6
26					5
27 14 22 40	+23·3	+122·0	*46	1922 July 2	11
28					11
29					10
30 13 5 30	+13·5	+143·0	11	1917 Nov. 24	14
31					12

1922 *November*.

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1					10
2					6
3 12 50 10	− 7·6	+128·3	7†	1921 Mar. 30	12
4 3 19 36	+40·5	−122·0	13	1920 Mar. 20	
4 4 20 12	+37·0	+ 20·5	36	1922 July 2	14
5 23 26 20	−39·0	− 17·0	7	1921 Feb. 13	10
6					3
7 23 0 12	−27·5	− 72·8	*64		11
8 10 28 28	+46·0	+ 12·0	4		
8 20 16 20	+36·0	+141·0	5	1922 June 25	

1922 *December*—contd.

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	°	°			
7 22 4 6	+40·0	+ 20·0	9	1922 Dec. 7	
7 22 21 36	+31·5	+130·0	7	1922 Dec. 7	10
8 2 2 0	+31·5	+130·0	*25	1922 Dec. 7	
8 5 16 50	+31·5	+130·0	6	1922 Dec. 8	
8 6 45 0	+31·5	+130·0	5	1922 Dec. 8	
8 7 15 20	+31·5	+130·0	5	1922 Dec. 8	
8 8 8 40	+15·5	− 77·5	8	1914 Aug. 3	
8 13 39 0	+31·5	+130·0	5	1922 Dec. 8	
8 20 19 50	+31·5	+130·0	5	1922 Dec. 8	
8 22 33 10	+41·9	+142·1	*44	1921 Jan. 25	44
9					32
10					18
11					13
12					10
13 14 3 52	+24·5	+122·0	6		9
14 23 3 48	− 3·5	+146·5	43	1922 Jan. 1	14
15					16
16 10 39 40	+19·5	+144·0	8		10
17 0 50 48	+39·0	+ 73·0	*47	1918 Dec. 1	10
18 7 23 20	+40·0	+ 20·0	4	1922 Dec. 7	
18 12 34 48	+18·5	− 68·0	25	1921 May 22	
18 22 29 0	+33·5	+131·9	4	1921 Jan. 21	14
19 3 0 30	−27·5	− 72·8	7†	1922 Nov. 7	24
20					17
21					20
22					14
23 17 22 24	−27·5	− 72·8	10	1922 Dec. 19	
23 21 54 30	−19·0	−173·0	26	1921 Feb. 27	21
24 0 6 26	+21·0	+ 97·0	7		16
25 3 33 0	−43·0	+173·0	*38		15
					19

10	12	24	12	+13·5	+143·0	6	1922 Oct. 30	10
11	4	32	30	−29·0	− 71·0	*102†		
11	18	9	12	−29·0	− 71·0	*55	1922 Nov. 11	
11	22	13	0	+37·5	+ 23·0	21	1922 Aug. 19	
11	23	26	0	−29·0	− 71·0	15	1922 Nov. 11	48
12	7	9	0	−29·0	− 71·0	*30	1922 Nov. 11	39
13	3	56	0	+65·5	− 19·5	15		76
14								25
15								34
16								35
17	11	2	42	−29·0	− 71·0	*64	1922 Nov. 12	21
18	18	56	24	+24·0	+120·0	14	1922 Sept. 4	17
19	17	4	26	+36·5	+ 1·5	10	1922 Aug. 25	19
20	4	24	44	+37·5	+ 29·0	5	1920 July 4	
20	15	29	20	+ 8·0	− 37·5	12	1915 Sept. 12	25
21								19
22								14
23								10
24	2	15	40	+45·5	+ 19·0	15		8
25								10
26	13	30	0	−29·0	− 71·0	25	1922 Nov. 17	18
27								8
28								9
29								21
30								8

1922 *December.*

1								12
2	3	46	36	+24·0	+120·0	*40	1922 Nov. 18	15
3	14	42	48	+45·2	+140·2	7		14
4								17
5								10
6	13	55	26	+36·8	+ 69·5	*65†		10
7	16	22	10	+40·0	+ 20·0	35	1922 Jan. 12	
7	16	37	6	+40·0	+ 20·0	14	1922 Dec. 7	
7	16	50	0	+31·5	+130·0	*43		
28	12	40	42	−29·0	− 71·0	14	1922 Nov. 26	11
29	12	22	10	+42·0	+ 13·5	25	1918 Apr. 18	7
30								6
31	7	19	56	+45·5	+151·2	*74		13

1923 *January.*

1								18
2	22	42	0	+25·0	+121·5	*20	1922 Oct. 14	21
3	9	41	28	−30·0	− 70·0	5		22
4								16
5	17	50	45	− 7·0	+150·0	10	1920 Feb. 9	20
6								22
7	12	27	15	+41·0	+ 23·0	12	1922 Sept. 5	
7	13	20	6	+41·0	+ 23·0	5	1923 Jan. 7	12
8								37
9								24
10								21
11	4	29	0	+41·8	−122·0	8		
11	12	24	30	+31·5	+130·0	5	1922 Dec. 8	23
12	1	54	28	−30·0	− 70·0	*17	1923 Jan. 3	28
13	9	39	50	−69·0	+ 10·0	14		13
14	5	51	35	+37·0	+138·5	11†	1922 June 7	14
15								13
16								14
17								19
18								7
19								14
20	21	36	27	−30·0	− 70·0	7	1923 Jan. 12	14
21	4	13	30	+37·0	+ 20·5	27	1922 Nov. 4	
21	13	37	42	−20·0	+176·5	7	1920 Mar. 15	12
22	0	54	45	−20·0	+176·5	*26	1923 Jan. 21	
22	9	4	8	+39·7	−124·6	71†		15
23								15
24								14
25								12
26	3	23	50	+19·5	+137·5	*6		

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1923 *January*—contd.					
	°	°			
26 21 27 40	+19·5	+137·5	14		17
27 4 12 45	+38·3	+141·0	4	1920 Dec. 19	
27 5 4 0	+38·3	+141·0	6	1923 Jan. 27	
27 8 4 0	+39·7	−105·0	28		42
28					12
29					21
30					10
31					12
1923 *February*.					
1 19 24 54	−21·5	+169·0	46		
1 21 34 0	−21·5	+169·0	6	1923 Feb. 1	11
2 1 6 15	+50·5	+164·0	*52†	1915 July 31	
2 5 7 15	+50·5	+164·0	*85†	1923 Feb. 2	26
3 16 1 36	+54·0	+161·0	*102	1919 May 27	
3 17 40 50	+54·0	+161·0	*12	1923 Feb. 3	
3 18 42 45	+54·0	+161·0	*35	1923 Feb. 3	
3 18 50 30	+54·0	+161·0	*14	1923 Feb. 3	49
4 15 46 48	−31·0	− 72·0	5	1917 July 27	82
5 21 27 12	+39·0	+143·5	5		
5 22 23 10	+50·5	+164·0	*22	1923 Feb. 2	
5 22 58 20	+50·5	+164·0	18	1923 Feb. 5	54
6 15 21 32	+43·5	+ 17·0	29	1920 June 20	46
7					21
8 0 33 24	+18·2	− 97·5	*17	1920 Jan. 4	44
9					27
10					27
11 18 26 24	+37·0	+141·0	6	1922 June 3	
11 22 45 34	+55·0	+162·5	*49		20

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1923 *March*—contd.					
	°	°			
14 20 44 8	+ 5·6	+126·3	*47	1921 June 9	10
15 5 40 20	+43·5	+ 17·0	49	1923 Feb. 6	
15 6 2 52	+19·5	− 65·0	14		33
16 22 1 30	+ 6·5	+127·0	*74	1920 Feb. 25	17
17 16 1 33	+23·5	+119·0	7	1922 Apr. 7	26
18 20 29 30	+33·6	−111·4	8	1921 Mar. 25	20
19 11 13 6	+ 6·0	− 84·0	15	1920 July 16	27
20 8 48 10	+43·7	+144·4	4	1920 Sept. 27	13
21 8 28 54	+46·0	+149·0	10	1922 Apr. 25	9
22 7 46 30	+19·0	+144·0	9	1919 Aug. 27	16
23					10
24 12 40 10	+31·5	+100·5	*84	1919 May 29	11
25					10
26 13 43 0	−30·2	+ 75·0	17	1918 Aug. 26	25
27					8
28 4 28 20	− 7·0	+124·0	*29		
28 20 29 12	− 5·5	+130·0	7†	1921 Mar. 24	19
29					9
30 10 12 0	+43·4	+ 19·2	4		4
31					9
1923 *April*.					
1					6
2					12
3 7 7 20	+38·0	+ 20·5	9	1921 Sept. 14	11
4					13
5 22 9 40	+25·0	+121·5	12	1923 Jan. 2	5
6					9
7					6
8					6

12	[illegible]	30	[illegible]	+39·[illegible]	+1[illegible]7·[illegible]	[illegible]8	1922 June [illegible]	20
14								15
15	9	42	35	− 6·5	+126·0	11	1920 May 19	
15	22	38	38	+55·0	+162·5	18	1923 Feb. 12	13
16	6	37	15	+55·0	+162·5	17	1923 Feb. 15	
16	9	16	10	+48·8	+153·5	*31		9
17								8
18	23	39	20	+55·0	+162·5	22	1923 Feb. 16	14
19	6	17	5	− 5·0	+135·0	17†	1921 Oct. 10	12
20	10	6	20	+22·0	+123·5	3	1921 Sept. 5	10
21	0	55	18	+55·0	+162·5	*15	1923 Feb. 18	
21	3	50	28	+55·0	+162·5	*18	1923 Feb. 21	13
22								6
23	5	51	50	0·0	+122·4	*46	1922 Sept. 11	8
24	7	34	30	+55·0	+162·5	*94†	1923 Feb. 21	9
25	2	24	42	−29·5	− 71·0	5		17
26								12
27	20	37	20	+37·7	−118·5	13	1919 Feb. 16	13
28	22	18	30	+44·0	− 25·8	21		9

1923 *March.*

1	8	26	16	+52·5	−166·5	*23		24
2	16	48	36	+ 6·0	+125·0	*79†	1917 Nov. 18	11
3	10	24	36	+41·0	+131·0	7		
3	21	52	50	− 1·0	+100·5	*27		12
4	0	9	16	0·0	− 24·8	29†		
4	6	53	8	−17·0	−177·5	*30	1920 Mar. 22	11
5								9
6	21	6	54	0·0	+ 70·0	9		6
7								12
8								19
9	22	56	12	−29·0	− 71·0	9	1922 Dec. 28	12
10	19	48	40	+34·5	+ 27·5	30		19
11	23	6	30	+41·1	−126·6	14	1922 Jan. 31	11
12	9	42	26	+39·5	+145·0	12	1922 Apr. 12	11
13	19	59	12	+55·5	−152·0	21	1917 Dec. 28	9

10								9
11								11
12								11
13	2	26	30	+ 2·0	+ 96·0	*7	1920 Mar. 17	
13	10	3	5	−23·5	+178·0	*29	1921 May 16	
13	15	30	54	+55·7	+162·5	*76		22
14								24
15								12
16	15	8	54	+41·9	+142·1	3	1922 Dec. 8	7
17	16	55	50	+ 2·5	+118·5	8		4
18								5
19	3	9	0	+ 2·5	+118·5	*58	1923 Apr. 17	12
20								12
21	17	12	40	−30·5	− 70·0	6		8
22								7
23	3	16	40	+29·0	+122·5	*60†		28
24	5	31	30	0·0	+122·4	8	1923 Feb. 23	
24	14	3	12	−31·2	− 69·6	8		
24	22	3	6	+29·6	+ 87·8	14	1918 Feb. 4	
24	22	44	42	+59·0	−135·5	17		11
25	19	31	56	+59·0	−135·5	23	1923 Apr. 24	8
26								4
27	7	15	56	+41·0	+140·0	8		
27	10	26	4	− 1·0	+127·0	16		9
28								7
29	2	31	24	+40·5	−122·0	13	1922 Nov. 4	
29	9	33	50	+43·5	+ 16·5	14		
29	9	34	20	+40·0	+ 37·0	*40		19
30	4	34	50	+43·5	+ 16·5	6	1923 Apr. 29	
30	19	51	30	+ 1·0	+143·5	15	1918 Mar. 14	28
30	23	31	40	+43·5	+ 16·5	19	1923 Apr. 30	

1923 *May.*

1	10	36	10	−55·0	− 24·0	*35		14
2	16	23	36	+50·0	−128·0	22	1920 Nov. 28	24
3	14	5	20	+42·3	+ 17·8	5	1918 June 29	15

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1923 *May*—contd.			
	°	°			
4 10 41 0	+23·2	+120·6	6		
4 16 26 32	+54·5	−156·5	*85		
4 17 30 28	+42·0	+141·0	6	1920 June 25	
4 22 26 40	−28·5	− 71·5	*53	1922 July 28	4
5 15 4 5	+41·1	−126·6	12	1923 Mar. 11	13
6 11 24 30	+35·5	+142·0	5	1922 Aug. 6	
6 22 53 55	+35·0	+ 22·5	9	1922 July 22	3
7 3 2 18	+36·2	+142·2	4		
7 13 10 48	+36·2	+142·2	10		17
8					14
9 18 33 6	+35·0	+ 22·5	7	1923 May 6	15
10 3 44 48	−55·2	− 23·0	*25		11
11 8 24 12	−14·0	+166·5	*8†	1922 Apr. 11	
11 8 42 40	+41·5	− 7·0	4	1920 Nov. 26	12
12 1 19 50	− 8·0	+105·0	*42	1919 July 29	
12 22 57 23	+40·5	+ 45·0	13		10
13					14
14 7 2 32	+16·0	+153·5	4		10
15 4 11 10	− 8·0	+105·0	9	1923 May 12	
15 21 29 2	−15·0	−172·0	*16	1921 July 29	14
16 18 4 13	−27·0	−176·0	*10		13
17 10 36 54	+35·0	− 5·0	10		10
18					13
19					13
20 20 51 45	+39·3	+ 21·0	21	1921 June 26	16
21 22 58 36	+39·3	+ 21·0	7	1923 May 20	14
22 10 9 40	+45·0	+ 16·0	8	1921 Jan. 1	13
23 22 37 0	+53·2	+162·6	*72		19
24					12
25 22 21 25	+32·0	+ 57·0	39		
25 23 35 35	+ 6·5	+128·0	4	1920 Aug. 3	10

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1923 *June*—contd.			
	°	°			
13 11 31 56	+41·5	+143·0	3		6
14					14
15 11 8 50	+36·0	+142·0	5	1923 June 12	18
16 13 5 30	+36·0	+142·0	7	1923 June 15	19
17 18 2 54	+68·5	− 19·5	13		16
18 4 18 40	+34·8	+ 46·0	3		
18 8 15 45	−18·5	−176·0	*72		
18 11 28 10	+36·0	+142·0	8	1923 June 16	18
19 7 1 10	+36·0	+142·0	5	1923 June 18	
19 22 43 30	+61·8	−151·0	44		8
20					15
21 12 25 0	+40·5	+ 82·5	15		8
22 3 46 54	+56·0	−136·0	11	1920 May 8	
22 6 44 30	+22·7	+ 99·0	*80		
22 12 6 4	+22·7	+ 99·0	10	1923 June 22	
22 20 45 54	−15·0	+165·0	20	1919 Aug. 31	12
23 15 16 57	+24·0	+123·0	5	1922 Sept. 6	4
24					11
25					20
26					9
27					6
28 15 11 30	+45·0	+ 11·0	23		20
29 10 47 38	+28·5	+141·5	9†		
29 10 53 20	+28·5	+141·5	*8†	1923 June 29	8
30					14
		1923 *July*.			
1 7 54 55	+22·0	+100·5	23		9
2 2 31 55	+25·0	+121·5	*50	1923 Apr. 5	29
3 6 25 45	+37·0	+ 20·5	7	1923 Jan. 21	6

26	3	13	30	+36·5	+140·5	*30	1923 Jan. 14	
26	5	29	32	+36·5	+140·5	5	1923 May 26	
26	8	42	48	−11·0	+134·0	14		19
27	16	21	36	−28·5	− 71·5	15	1923 May 4	17
28	1	25	48	− 1·0	+ 89·0	*51		24
29	11	34	20	+41·0	+ 30·0	13		17
30	8	30	30	+76·5	+127·0	*43		
30	17	56	42	+76·5	+127·0	46	1923 May 30	26
31	5	55	35	+35·5	+143·5	*31		
31	6	10	32	+35·5	+143·5	6	1923 May 31	
31	22	5	48	+31·3	− 41·0	34		18
				1923 *June.*				
1	15	31	25	−30·0	− 70·0	10	1923 Jan. 20	
1	17	24	35	+36·0	+142·0	*87		
1	20	15	35	+36·0	+142·0	*78	1923 June 1	19
2	0	47	0	+36·0	+142·0	6	1923 June 1	
2	0	54	36	+40·8	+ 24·5	8		
2	1	1	15	−54·0	− 22·5	25		
2	3	12	30	+36·0	+142·0	7	1923 June 2	
2	4	53	45	+36·0	+142·0	2	1923 June 2	
2	12	39	30	−30·2	−179·0	*12	1920 Mar. 11	
2	14	18	35	−30·2	−179·0	9	1923 June 2	32
2	21	58	10	+36·0	+142·0	5	1923 June 2	
3	11	33	15	−56·0	− 10·0	*16		23
4	4	39	50	+36·0	+142·0	4	1923 June 2	
4	18	52	20	+36·0	+142·0	5	1923 June 4	
4	20	33	0	+35·5	+ 25·5	23		33
5	2	7	4	+36·0	+142·0	9	1923 June 4	11
6	17	36	30	+36·0	+142·0	*39	1923 June 5	
6	19	25	36	+65·0	+ 28·0	5		27
7								15
8								12
9								4
10								19
11								12
12	16	49	35	+36·0	+142·0	4	1923 June 6	10
4	5	29	28	+ 1·8	− 82·3	*9		
4	8	15	12	+ 1·8	− 82·3	16	1923 July 4	
4	16	3	40	+43·0	+ 44·0	6	1922 Mar. 2	
4	16	49	35	−18·0	− 66·0	13	1921 Oct. 20	
4	22	54	55	−28·0	−163·5	13		12
5								26
6								11
7	6	9	54	+52·0	−142·5	11		
7	12	46	40	−42·5	+174·0	*13		19
8	7	2	56	+19·5	+120·0	10	1922 June 1	
8	8	38	30	+40·0	+ 20·0	10	1922 Dec. 18	7
9	15	31	6	+35·5	− 5·5	27		16
10	0	28	54	−30·5	− 73·0	*40		
10	5	31	12	+42·8	− 1·0	38		
10	7	6	48	+42·8	− 1·0	8		28
11								15
12	3	15	30	−16·5	180·0	*45	1921 July 3	
12	9	13	40	−16·5	180·0	*24	1923 July 12	26
13	11	13	33	+31·5	+130·0	*82	1923 Jan. 11	
13	18	36	25	+17·3	+120·5	8	1919 Sept. 26	
13	23	56	15	+31·5	+130·0	*45	1923 July 13	36
14								35
15								11
16	13	23	36	+37·5	+ 70·5	14	1917 Apr. 21	
16	13	38	25	−16·0	+168·0	*34	1920 Jan. 22	19
17	0	20	35	− 8·0	+127·5	*9	1921 Mar. 23	
17	1	2	10	+63·0	−144·0	15		11
18	1	5	50	+43·2	− 29·5	30		
18	2	41	46	+ 9·5	+128·8	*9	1913 Apr. 25	22
18	6	2	4	+43·2	− 29·5	31	1923 July 18	
19	7	13	30	+12·5	+124·5	6	1922 Apr. 23	8
20	4	46	48	−28·5	− 71·5	15	1923 May 27	
20	15	2	33	− 1·5	− 13·4	*50		
20	16	49	42	+38·5	+135·0	12		
20	21	40	50	+42·0	+142·0	8		18
21	8	30	40	+36·0	+142·0	7	1923 June 19	
21	14	1	30	+41·5	− 40·0	12		21
22	0	16	4	−28·5	− 71·5	7	1923 July 20	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1923 *July*—contd.					
	°	°			
22 12 45 15	+45·0	+ 29·0	7†		
22 14 17 54	+51·6	+172·0	*65		15
23 7 30 18	+33·0	−119·0	*27		45
24 3 32 50	−28·5	− 71·5	6	1923 July 22	18
25 12 28 46	+34·0	+ 14·0	15	1920 Aug. 16	18
26 3 11 30	+32·5	+143·0	15	1922 May 1	
26 7 27 30	− 1·2	+149·5	9	1920 Feb. 9	
26 9 55 30	− 1·2	+149·5	*15	1923 July 26	
26 23 37 6	+41·0	+131·0	10	1923 Mar. 3	8
27 11 24 54	+ 1·0	+101·0	9		11
28 10 48 20	+33·0	+140·0	5		16
29 9 37 20	+37·5	+ 70·5	9	1923 July 16	14
30					4
31 1 38 35	+36·0	+ 21·5	9	1922 Apr. 20	
31 5 34 55	−13·0	− 66·0	21		
31 15 8 0	+52·0	+175·0	*29		
31 16 33 26	−29·0	− 73·0	9		12
1923 *August*.					
1 4 29 42	−50·0	+ 31·5	*32		
1 8 16 30	+35·0	+ 24·0	*45	1922 July 12	22
2					16
3 1 56 0	+35·0	+ 24·0	9	1923 Aug. 1	
3 10 23 48	+54·0	−160·5	5	1922 July 5	
3 17 2 8	+15·0	+137·0	*7	1914 July 4	19
4 4 12 8	+38·5	+ 22·5	3	1919 July 25	23
5 1 10 0	−37·0	+175·0	6	1921 June 28	10
6 15 24 30	+37·5	+142·5	3	1921 June 14	13
7 7 27 50	−28·5	− 71·5	7	1923 July 24	
7 14 23 28	+32·5	+ 97·5	10		6

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1923 *August*—contd.					
	°	°			
28 23 15 12	+26·0	−107·0	*57		12
29					10
30 2 47 8	+ 9·0	+128·0	*7	1913 Apr. 29	13
31 2 15 50	+38·5	+ 71·0	18		
31 11 9 30	+ 5·4	+125·2	4†	1919 Jan. 4	
31 11 14 30	+ 5·4	+125·2	9	1923 Aug. 31	18
1923 *September*.					
1 2 58 28	+35·0	+139·5	*102†	1922 Apr. 26	
1 3 24 20	+35·0	+139·5	6	1923 Sept. 1	
1 3 34 6	+35·0	+139·5	2	1923 Sept. 1	
1 3 39 30	+35·0	+139·5	4	1923 Sept. 1	
1 3 40 30	+35·0	+139·5	3	1923 Sept. 1	
1 3 48 15	+35·0	+139·5	6	1923 Sept. 1	
1 4 11 0	+35·0	+139·5	3	1923 Sept. 1	
1 4 13 30	+35·0	+139·5	1	1923 Sept. 1	
1 4 20 20	+35·0	+139·5	5	1923 Sept. 1	
1 4 27 0	+35·0	+139·5	2	1923 Sept. 1	
1 4 31 0	+35·0	+139·5	6	1923 Sept. 1	
1 4 45 20	+35·0	+139·5	2	1923 Sept. 1	
1 4 58 40	+35·0	+139·5	6	1923 Sept. 1	
1 5 12 50	+35·0	+139·5	5	1923 Sept. 1	
1 5 22 30	+35·0	+139·5	*15	1923 Sept. 1	
1 5 41 (0)	+35·0	+139·5	1	1923 Sept. 1	
1 5 54 0	+35·0	+139·5	3	1923 Sept. 1	
1 6 5 5	+35·0	+139·5	5	1923 Sept. 1	
1 6 13 50	+35·0	+139·5	3	1923 Sept. 1	
1 6 19 0	+35·0	+139·5	9	1923 Sept. 1	
1 6 40 0	+35·0	+139·5	3	1923 Sept. 1	
1 6 43 2	+35·0	+139·5	2	1923 Sept. 1	

[illegible]	[illegible]	[illegible]	[illegible]	1918 Dec. 14		[illegible]	+35·0	+139·5	4	1923 Sept. 1
8 12 1 27	+10·6	− 65·6	*42†			1 7 23 40	+35·0	+139·5	2	1923 Sept. 1
8 12 17 20	0·0	− 28·2	*34	1920 Nov. 12	10	1 7 38 0	+35·0	+139·5	*44	1923 Sept. 1
9					14	1 8 1 30	+35·0	+139·5	1	1923 Sept. 1
10 1 0 34	+41·0	+ 77·5	10			1 8 11 20	+35·0	+139·5	3	1923 Sept. 1
10 2 17 20	+41·0	+ 77·5	21	1923 Aug. 10		1 8 32 30	+35·0	+139·5	1	1923 Sept. 1
10 15 58 6	+22·6	+ 93·4	*33			1 9 0 0	+35·0	+139·5	3	1923 Sept. 1
10 22 14 38	− 7·0	+145·0	*19	1922 Aug. 26	15	1 9 31 0	+35·0	+139·5	1	1923 Sept. 1
11 0 54 15	+ 5·0	+120·0	*49			1 11 41 50	+35·0	+139·5	1	1923 Sept. 1
11 7 45 20	+40·0	+125·0	4		13	1 12 47 0	+35·0	+139·5	1	1923 Sept. 1
12 5 59 30	+11·5	+149·0	*30†			1 12 58 20	+35·0	+139·5	2	1923 Sept. 1
12 10 6 12	+28·0	+126·0	*52			1 13 3 30	+35·0	+139·5	1	1923 Sept. 1
12 17 16 36	− 1·5	− 23·0	20		13	1 13 22 10	+35·0	+139·5	1	1923 Sept. 1
13					9	1 13 33 40	+35·0	+139·5	1	1923 Sept. 1
14 17 51 0	+39·5	+ 24·0	23			1 13 39 25	+35·0	+139·5	1	1923 Sept. 1
14 21 24 14	+42·0	+142·0	3	1923 July 20	8	1 13 52 15	+35·0	+139·5	15	1923 Sept. 1
15					27	1 14 30 0	+35·0	+139·5	3	1923 Sept. 1
16 3 51 40	+40·2	+ 34·4	19			1 15 0 30	+35·0	+139·5	1	1923 Sept. 1
16 20 22 30	+46·5	+151·5	*37	1921 Mar. 29	18	1 15 40 30	+35·0	+139·5	8	1923 Sept. 1
17 0 32 28	+38·0	+ 18·5	6			1 16 12 10	+35·0	+139·5	2	1923 Sept. 1
17 1 5 5	−24·0	− 69·0	*33	1916 Dec. 23		1 16 35 50	+35·0	+139·5	3	1923 Sept. 1
17 3 46 38	+48·0	+148·0	*22	1919 Sept. 12		1 16 52 30	+35·0	+139·5	1	1923 Sept. 1
17 12 10 25	− 9·0	+141·0	*23		17	1 17 0 0	+35·0	+139·5	2	1923 Sept. 1
18					14	1 17 2 30	+35·0	+139·5	11	1923 Sept. 1
19 12 21 50	− 1·0	+154·0	*27	1918 June 24		1 17 13 30	+35·0	+139·5	2	1923 Sept. 1
19 22 23 18	+38·5	+139·0	6		16	1 18 0 20	+35·0	+139·5	4	1923 Sept. 1
20 18 9 30	− 8·5	+125·5	*17	1918 Oct. 16		1 18 37 0	+35·0	+139·5	2	1923 Sept. 1
20 19 13 42	− 8·5	+125·5	*11	1923 Aug. 20	11	1 19 8 40	+35·0	+139·5	10	1923 Sept. 1
21					16	1 19 14 0	+35·0	+139·5	2	1923 Sept. 1
22 14 45 42	+46·0	+149·0	5	1923 Mar. 21	12	1 20 14 50	+35·0	+139·5	1	1923 Sept. 1
23 5 12 45	− 5·0	− 95·0	12		7	1 21 8 40	+35·0	+139·5	2	1923 Sept. 1
24 1 15 22	+38·5	+139·0	8	1923 Aug. 19		1 21 12 0	+35·0	+139·5	2	1923 Sept. 1
24 7 25 40	+17·0	+122·0	8			1 21 48 40	+35·0	+139·5	12	1923 Sept. 1
24 9 2 20	+17·0	+122·0	7	1923 Aug. 24	13	1 22 11 0	+35·0	+139·5	4	1923 Sept. 1
25					14	1 22 11 40	+35·0	+139·5	1	1923 Sept. 1
26					11	1 22 29 0	+35·0	+139·5	1	1923 Sept. 1
27 11 15 0	+24·8	+120·4	17		17	1 22 35 0	+35·0	+139·5	1	1923 Sept. 1
28 6 46 38	+38·5	+ 22·5	5	1923 Aug. 4		1 22 50 40	+35·0	+139·5	3	1923 Sept. 1

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

1923 *September*—contd.

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1 23 1 20	+35·0	+139·5	2	1923 Sept. 1	
1 23 14 0	+35·0	+139·5	1	1923 Sept. 1	
1 23 36 0	+35·0	+139·5	2	1923 Sept. 1	
1 23 47 0	+35·0	+139·5	1	1923 Sept. 1	21
2 0 59 54	+35·0	+139·5	12	1923 Sept. 1	
2 2 46 40	+35·0	+139·5	*93†	1923 Sept. 2	
2 4 37 32	+35·0	+139·5	1	1923 Sept. 2	
2 4 47 58	+35·0	+139·5	5	1923 Sept. 2	
2 5 5 42	+35·0	+139·5	1	1923 Sept. 2	
2 5 10 10	+35·0	+139·5	6	1923 Sept. 2	
2 6 2 0	+35·0	+139·5	1	1923 Sept. 2	
2 6 32 30	+35·0	+139·5	3	1923 Sept. 2	
2 9 26 56	+35·0	+139·5	*69†	1923 Sept. 2	
2 9 48 50	+35·0	+139·5	6	1923 Sept. 2	
2 10 21 0	+35·0	+139·5	1	1923 Sept. 2	
2 11 11 0	+35·0	+139·5	1	1923 Sept. 2	
2 11 43 30	+35·0	+139·5	1	1923 Sept. 2	
2 12 54 30	+35·0	+139·5	2	1923 Sept. 2	
2 13 9 10	+35·0	+139·5	*34†	1923 Sept. 2	
2 14 16 28	+35·0	+139·5	*28†	1923 Sept. 2	
2 21 2 0	+35·0	+139·5	2	1923 Sept. 2	
2 22 38 0	−15·0	− 66·0	*60		44
3 0 9 18	+35·0	+139·5	5	1923 Sept. 2	
3 0 40 16	+35·0	+139·5	3	1923 Sept. 3	
3 1 47 12	+35·0	+139·5	9	1923 Sept. 3	
3 5 21 36	+35·0	+139·5	2	1923 Sept. 3	
3 6 2 0	+35·0	+139·5	3	1923 Sept. 3	
3 8 13 40	+35·0	+139·5	3	1923 Sept. 3	
3 9 23 54	+35·0	+139·5	2	1923 Sept. 3	
3 14 30 30	+35·0	+139·5	6	1923 Sept. 3	19

1923 *September*—contd.

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
22 20 47 33	+29·5	+ 56·0	74		21
23 3 18 58	+29·5	+ 56·0	13	1923 Sept. 22	
23 17 28 44	+56·0	−150·0	*15		
23 20 56 38	+52·8	+155·2	*8		5
24					32
25					11
26 1 18 48	+43·8	+ 15·7	24		
26 2 29 10	+ 1·0	− 30·0	*38		
26 8 23 40	+35·0	+139·5	*64	1923 Sept. 17	13
27 7 1 0	+ 8·0	+126·5	*26		
27 22 57 30	+41·0	+ 19·5	8		17
28 21 0 12	+ 3·0	− 85·0	17		13
29 3 0 40	+36·0	+138·0	3	1918 Nov. 24	
29 6 49 30	+22·0	+123·5	*18	1923 Feb. 20	20
30 1 20 35	+54·5	− 33·0	*75		
30 23 10 15	+35·5	+ 77·0	9		24

1923 *October*.

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1 3 7 20	+42·5	+ 15·5	7		
1 8 16 25	+31·2	+ 70·3	41		
1 10 40 28	+42·5	+ 15·5	15	1923 Oct. 1	
1 22 27 30	−32·0	−179·0	*35		24
2 1 25 18	+38·5	+136·0	3		
2 11 22 20	+31·2	+ 70·3	8	1923 Oct. 1	5
3 14 8 18	+35·0	+139·5	3	1923 Sept. 26	
3 15 54 5	+35·0	+139·5	*30	1923 Oct. 3	11
4 7 37 4	+ 5·6	+126·3	5	1923 Mar. 14	
4 17 31 10	−14·0	− 61·5	21		12
[illegible]	[illegible]	[illegible]	7	1923 Oct. 3	14

4	5	37	30	+35·0	+139·5	3	1923 Sept. 4	
4	10	10	34	+35·0	+139·5	2	1923 Sept. 4	
4	15	24	42	+35·0	+139·5	4	1923 Sept. 4	
4	18	15	36	+35·0	+139·5	2	1923 Sept. 4	
4	22	22	48	+35·0	+139·5	9	1923 Sept. 4	18
5	9	34	34	+35·0	+139·5	2	1923 Sept. 4	
5	11	12	36	+35·0	+139·5	4	1923 Sept. 5	
5	15	20	0	− 1·5	+ 93·5	7		10
5	18	29	40	+35·0	+139·5	16	1923 Sept. 5	
5	18	46	4	+35·0	+139·5	3	1923 Sept. 5	
6								6
7	14	30	16	+35·0	+139·5	4	1923 Sept. 5	
7	15	16	50	+35·0	+139·5	6	1923 Sept. 7	
7	17	32	30	+35·0	+139·5	11	1923 Sept. 7	
7	23	39	32	+35·0	+139·5	5	1923 Sept. 7	11
8	9	8	42	+35·0	+139·5	11	1923 Sept. 7	30
9	4	16	44	− 5·0	− 80·0	*9†		
9	17	11	0	+35·0	+139·5	10	1923 Sept. 8	
9	22	3	42	+25·5	+ 91·5	*78		29
10	9	37	12	+72·0	− 8·5	19	1922 Apr. 8	24
11	9	7	50	+46·5	− 28·3	17	1922 Feb. 16	
11	10	14	48	+38·0	+ 29·5	8	1920 Sept. 28	13
12	5	53	48	−17·0	−177·5	*20	1923 Mar. 4	13
13								16
14	8	10	30	+29·5	+ 59·5	14		
14	12	57	24	+47·0	+ 95·0	35		25
15								20
16	16	34	30	− 3·0	+138·0	*45		25
17	1	2	10	+35·0	+139·5	4	1923 Sept. 9	
17	3	39	20	+31·0	+140·0	*28		
17	7	9	4	+35·5	+ 55·0	53		9
18	6	34	25	+35·5	+ 14·5	8		16
19	8	22	30	+12·5	+168·0	13		
19	16	29	30	+38·0	+ 23·7	8		24
20								23
21	20	1	22	+50·5	+ 86·5	34		26
22	2	52	56	+38·5	+135·0	5	1923 July 20	
22	14	55	30	− 3·0	+143·5	*17	1917 Nov. 28	

6								16
7	3	29	30	− 1·0	+129·0	*90		13
8	3	41	46	+ 6·7	− 84·4	10		14
9	11	22	42	+39·5	+140·5	7		
9	22	44	6	+39·3	+ 21·0	1	1923 May 21	
9	22	46	37	+39·3	+ 21·0	1	1923 Oct. 9	
9	22	52	22	+39·3	+ 21·0	1	1923 Oct. 9	
9	23	2	51	+39·3	+ 21·0	3	1923 Oct. 9	
9	23	5	11	+39·3	+ 21·0	2	1923 Oct. 9	
9	23	10	30	+39·3	+ 21·0	14	1923 Oct. 9	
9	23	15	11	+39·3	+ 21·0	3	1923 Oct. 9	
9	23	37	23	+39·3	+ 21·0	1	1923 Oct. 9	
9	23	47	54	+39·3	+ 21·0	5	1923 Oct. 9	11
10	7	11	8	+71·0	− 12·0	*73		12
11	12	28	48	+44·0	− 39·5	19		11
12								13
13	4	28	24	+50·5	−129·5	20	1920 Mar. 29	11
14								19
15	3	49	10	+31·2	+ 70·3	8	1923 Oct. 2	
15	7	31	48	− 9·0	+121·0	*31†		
15	7	57	55	− 9·0	+121·0	*34†	1923 Oct. 15	
15	12	48	0	+11·0	+127·0	*5	1921 Nov. 18	
15	20	10	10	+58·5	+163·0	7		8
16	18	4	0	+35·0	+139·5	8	1923 Oct. 5	15
17	12	11	46	−50·0	− 24·0	8		24
18	0	51	50	+44·8	+ 14·7	9		20
19	9	2	0	+36·0	− 5·0	8		8
20	0	24	0	+65·0	− 15·0	17		
20	3	18	48	+30·0	+ 99·0	33		
20	10	1	40	+ 4·0	+139·0	6		14
21								19
22	5	25	20	−58·5	+145·5	10		
22	19	45	45	+35·0	+139·5	4	1923 Oct. 16	18
23	16	37	22	+65·0	− 15·0	6	1923 Oct. 20	7
24								9
25								9
26	12	13	16	+41·2	+ 28·6	8		28
27								11

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	1923 *October*—contd.				
	°	°			
28 9 28 12	+46·0	+ 89·0	5		21
29					16
30 19 34 12	+40·0	+ 20·0	6	1923 July 8	13
31 16 37 30	+35·0	+139·5	3	1923 Oct. 22	11
	1923 *November*.				
1 20 2 10	+33·6	−111·4	16	1923 Mar. 18	31
2 21 7 54	− 5·7	+151·8	*90	1918 Dec. 9	9
3 4 49 0	− 5·7	+151·8	*19	1923 Nov. 2	
3 8 37 40	+19·0	− 74·0	*35†		
3 16 19 12	+29·0	+130·0	*76	1921 July 4	27
4 0 4 20	− 5·7	+151·8	*76	1923 Nov. 3	
4 11 55 0	−19·5	−174·2	9	1918 Oct. 14	
4 18 36 36	+37·5	+142·5	5	1923 Aug. 6	
4 20 3 10	− 5·7	+151·8	*21	1923 Nov. 4	
4 20 45 40	+35·0	+139·5	12	1923 Oct. 31	
4 22 13 20	− 5·7	+151·8	11	1923 Nov. 4	14
5 21 27 52	+29·0	+130·0	*82	1923 Nov. 3	22
6 13 36 8	+38·7	+136·0	5		
6 17 15 12	−38·0	− 73·5	*38	1922 Mar. 12	
6 19 18 34	+29·0	+130·0	*38	1923 Nov. 5	19
7 3 48 15	+ 4·0	+144·0	4	1919 June 10	
7 4 52 50	+40·8	+ 0·5	10	1919 Nov. 29	
7 23 56 52	+31·0	−116·0	*23		9
8 12 29 0	+43·0	+ 15·0	8	1920 June 25	16
9 3 19 28	+16·0	−103·0	27		
9 13 22 34	+46·0	+ 9·0	3	1920 Oct. 22	7
10 0 57 40	+37·5	+142·5	7	1923 Nov. 4	
10 21 22 15	−16·0	+168·0	13	1923 July 16	14
11 4 57 45	+25·0	+120·5	*4	1923 Nov. 4	

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	1923 *December*—contd.				
	°	°			
4 23 39 0	+32·0	+127·5	10		17
5 20 56 40	+40·0	+ 24·0	*58		
5 22 35 6	− 1·0	+121·0	*42		5
6					31
7 15 53 8	+53·5	+158·5	*19		
7 23 36 40	−12·0	+102·0	*10		24
8 19 6 20	+32·0	+127·5	16	1923 Dec. 4	25
9					21
10 23 53 28	+13·5	+ 50·0	18		20
11 5 4 0	− 8·0	+ 95·0	*20		9
12 4 4 10	+34·0	+133·0	4		
12 16 27 0	−12·0	− 2·0	*16		14
13					14
14 10 31 18	+ 1·0	− 77·0	*30		18
15					14
16 7 36 40	+ 1·0	− 77·0	4	1923 Dec. 14	
16 11 48 20	+37·0	+ 81·0	6		23
17					17
18					10
19 15 38 4	+10·0	+127·5	4	1922 Apr. 13	
19 16 0 48	+42·3	+ 17·8	7	1923 May 3	
19 19 2 0	+ 0·5	+126·5	16†	1920 Dec. 18	20
20 15 13 20	+39·5	+ 72·0	13	1918 Sept. 12	17
21					15
22 9 56 0	+ 5·5	− 71·5	*33		18
23					27
24 3 39 54	+35·0	+139·5	10	1923 Nov. 23	9
25					12
26					26
27 7 17 12	+35·0	+139·0	4	1923 Dec. 24	
27 10 28 35	− 9·0	+163·0	8	1922 Aug. 26	

11	14	0	24	+84·0	+100·0	7		13
12	11	50	30	+52·5	−170·0	12	1921 Sept. 19	9
13								10
14								15
15	21	33	36	+35·0	+139·5	5	1923 Nov. 11	12
16	4	15	35	+53·0	−131·0	17		22
17	2	53	20	+51·0	−179·5	*42†	1921 Nov. 11	
17	20	40	30	+35·5	+141·0	9	1922 Aug. 24	5
18	21	29	20	+24·0	+123·0	*52	1923 June 23	18
19	2	19	0	+24·0	+123·0	13	1923 Nov. 18	
19	3	54	5	+42·5	+ 1·0	34		26
20								19
21	13	34	0	+37·5	+ 90·0	10		
21	16	32	36	+35·5	+141·0	4	1923 Nov. 17	
21	17	0	20	+35·5	+141·0	5	1923 Nov. 21	17
22	7	20	45	+24·0	+123·0	19	1923 Nov. 19	12
23	2	33	40	+35·0	+139·5	22	1923 Nov. 15	28
24	7	54	58	+37·0	− 7·5	12		
24	18	47	20	+39·2	+ 7·8	14		27
25	17	3	5	+24·0	+123·0	*37	1923 Nov. 22	14
26	6	7	54	−58·5	+153·0	6		
26	12	18	27	−31·0	+ 56·0	*33		17
27	3	21	0	+29·0	+133·0	15		16
28	0	34	8	+53·5	− 37·0	13		
28	6	6	55	+47·2	+ 13·7	12		
28	16	8	10	+37·7	+ 73·6	5		23
29	3	36	36	+31·2	+ 61·6	16		12
30								28

1923 *December*.

1								23
2	14	36	24	−17·5	+168·8	21		15
3	7	55	45	−37·0	+175·0	8	1923 Aug. 5	
3	8	36	20	+38·0	+137·5	4		12
4	0	50	10	+24·0	+120·0	3	1922 Dec. 2	
4	9	50	18	+38·0	+137·5	4	1923 Dec. 3	

28	22	24	42	+40·3	+ 69·5	44†		28
29								17
30								10
31	5	51	6	+35·0	+139·5	6	1923 Dec. 27	
31	15	20	0	− 8·5	+113·5	5		
31	19	48	42	+34·5	+ 25·0	11	1922 Sept. 22	13

1924 *January*.

1								27
2	8	55	8	+44·0	+ 13·0	31	1921 Apr. 5	9
3								11
4	12	20	45	+62·5	+ 94·0	7		
4	21	56	30	+39·7	−105·0	9	1923 Jan. 27	14
5								18
6								9
7	9	55	42	+55·0	−160·0	*23	1918 Sept. 12	5
8								12
9								11
10	23	43	50	+40·7	+145·8	14	1919 May 3	21
11								23
12	13	54	36	+54·5	+164·0	13	1917 Jan. 30	16
13	9	43	27	+43·8	+ 15·7	6	1923 Sept. 26	
13	19	14	47	+43·8	+ 15·7	8	1924 Jan. 13	
13	20	57	30	+43·8	+ 15·7	11	1924 Jan. 13	9
14	20	59	10	+35·0	+139·5	*81	1923 Dec. 31	17
15	2	55	0	−53·8	+148·0	14	1920 Mar. 11	
15	11	35	28	+22·0	+120·5	6		
15	19	23	58	+37·0	+141·0	8	1923 Feb. 11	18
16	21	37	54	−20·5	−178·5	*36†	1919 Jan. 1	12
17								15
18	14	56	20	+29·5	+ 56·0	15	1923 Sept. 23	14
19								23
20	15	33	48	+35·0	+139·5	3	1924 Jan. 14	
20	22	31	20	−23·0	− 66·0	8	1916 Aug. 25	12
21	1	52	48	+56·0	+145·5	*63		15
22	10	37	40	+42·0	+141·0	8	1923 May 4	

Catalogue of Earthquakes, 1918–1924—*contd.*

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1924 *January*—contd.					
22 11 4 50	+39·3	+ 33·2	22	1921 Sept. 26	8
23					6
24 2 22 45	+41·7	+ 8·5	5	1919 Aug. 24	
24 18 34 42	+ 7·0	+ 94·0	*16	1921 Mar. 5	14
25 5 56 20	− 2·6	−105·8	15	1923 July 4	
25 6 22 36	−18·5	+168·5	*14	1922 Aug. 3	11
26 2 6 10	− 1·5	− 76·0	8	1919 July 24	
26 3 21 0	−10·5	+161·0	7	1918 Oct. 27	
26 18 24 20	+32·5	+ 97·5	5	1923 Aug. 7	14
27 4 22 12	+20·0	+121·0	*24	1922 May 16	7
28 3 43 28	+ 1·0	− 70·0	3	1918 Dec. 21	9
29 1 54 50	−27·8	− 70·2	*69		
29 8 39 12	+45·0	+ 16·0	22	1923 May 22	12
30 0 5 24	+25·0	+ 93·0	21		
30 4 47 40	+13·5	+143·0	*23	1922 Nov. 10	
30 20 54 40	+20·0	− 77·5	21		19
31 0 58 40	−18·0	− 66·0	14	1923 July 4	18
1924 *February*.					
1					16
2 22 24 45	+35·0	+143·0	21	1923 Aug. 12	23
3					19
4					14
5					18
6					18
7 23 43 45	+43·8	+ 15·7	6	1924 Jan. 13	12
8					12
9 1 45 40	+43·8	+ 15·7	10	1924 Feb. 7	
9 8 18 40	+43·8	+ 15·7	10	1924 Feb. 9	

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1924 *March*—contd.					
7 20 59 45	− 1·0	+124·0	7		17
8					12
9					17
10 18 0 24	− 2·8	− 74·5	*13		5
11 10 41 8	+ 9·5	− 84·0	*50	1924 Mar. 4	
11 14 39 32	+47·0	+147·0	*27		
11 20 34 6	+ 9·5	− 84·0	19	1924 Mar. 11	
11 22 44 5	− 4·0	− 82·5	*26		23
12 2 50 20	+ 9·5	− 84·0	16	1924 Mar. 11	
12 13 52 40	+72·8	+ 2·5	29		
12 14 18 15	+72·8	+ 2·5	6	1924 Mar. 12	
12 23 3 45	+34·0	+142·5	7	1915 July 8	12
13 10 32 30	+45·0	+135·0	5	1924 Feb. 24	
13 10 41 54	+65·0	+153·0	13		
13 12 47 40	+16·0	+ 38·5	15	1915 Sept. 23	15
14 2 23 30	+54·5	+164·0	25	1924 Jan. 12	12
15 2 46 50	+10·0	+123·0	7	1922 Feb. 27	
15 10 31 12	+49·0	+144·0	*78	1922 Feb. 9	9
16 1 22 36	− 2·0	− 72·0	*19	1922 Jan. 17	
16 10 17 20	+35·0	+ 6·0	37		11
17					9
18 19 35 0	− 6·0	+105·0	*18	1919 Apr. 24	8
19					20
20 9 56 12	+ 9·5	− 84·0	12	1924 Mar. 12	16
21					9
22 12 51 55	+55·0	− 35·0	23	1919 Nov. 28	
22 13 8 38	+55·0	− 35·0	36	1924 Mar. 22	22
23					9
24 11 40 15	+ 9·5	− 84·0	7	1924 Mar. 20	
24 20 29 0	+ 9·5	− 84·0	*39	1924 Mar. 24	10
25 11 33 32	−53·8	+148·0	8	1924 Jan. 15	

10						22
11 5 57 24	− 8·0	+127·5	28	1923 July 17		
11 17 49 24	+35·0	+139·5	4	1924 Jan. 20	6	
12					3	
13 22 50 10	− 2·5	+121·0	*39		14	
14 18 55 30	+26·0	+ 96·0	18			
14 19 46 26	+43·8	+ 15·7	15	1924 Feb. 9	12	
15					16	
16 0 20 35	−15·0	+165·0	20	1923 June 22		
16 9 1 6	+37·5	+ 23·0	26	1922 Nov. 11	25	
17 20 12 25	−15·0	+165·0	11	1924 Feb. 16	17	
18 17 3 48	+35·2	+ 34·7	53	1919 Aug. 19	15	
19 6 59 45	+39·0	+ 47·5	45		21	
20					10	
21 13 16 18	+37·7	−118·5	10	1923 Feb. 27		
21 22 42 50	+35·0	+139·5	6	1924 Feb. 11	7	
22 15 32 40	+42·8	− 1·0	22	1923 July 10	29	
23					14	
24 5 45 10	+44·0	−127·0	20			
24 16 45 55	+45·0	+135·0	10†	1922 Sept. 15	7	
25					14	
26					21	
27 21 53 0	+42·5	+ 1·0	12	1923 Nov. 19	7	
28 10 44 42	+43·8	+ 15·7	19	1924 Feb. 14	10	
29 8 38 12	−50·0	+ 31·5	*32	1923 Aug. 1	7	
		1924 *March.*				
1 17 15 30	+43·8	+ 15·7	14	1924 Feb. 28	11	
2 6 45 40	+37·5	− 9·0	4	1921 Oct. 23	17	
3					14	
4 1 50 30	+37·0	0·0	3			
4 2 6 12	+ 9·5	− 84·0	6	1921 Feb. 11		
4 10 7 36	+ 9·5	− 84·0	*85	1924 Mar. 4		
4 11 43 36	+ 9·5	− 84·0	*32	1924 Mar. 4	20	
5 3 7 20	+35·0	+139·5	3	1924 Feb. 21		
5 4 24 54	+ 5·5	+130·0	*35†	1923 Mar. 28	27	
6 9 19 56	+19·5	− 66·0	5		10	
25 14 6 48	+ 9·5	− 84·0	*39	1924 Mar. 24		
25 15 3 18	+ 9·5	− 84·0	*31	1924 Mar. 25		
25 21 6 42	+43·0	+131·0	5†		13	
26 17 8 33	+47·0	+ 10·0	18	1918 Mar. 21		
26 20 2 20	−16·5	180·0	*28	1923 July 12		
26 20 22 50	+17·0	−112·0	7	1919 July 9		
26 20 51 30	+42·5	+ 15·5	8	1923 Oct. 1	23	
27 8 29 45	+ 9·5	− 84·0	*14	1924 Mar. 25	18	
28 4 57 0	+ 9·5	− 84·0	4	1924 Mar. 27		
28 5 0 15	+55·0	− 35·0	16	1924 Mar. 22		
28 13 54 12	+34·0	+140·0	4		8	
29					10	
30 0 8 55	+50·5	−129·5	*43	1923 Oct. 13	23	
31 16 51 50	+40·0	+ 76·0	6	1920 June 14	13	
		1924 *April.*				
1					19	
2					12	
3 1 17 30	−16·2	+165·4	16	1920 Oct. 24		
3 2 30 30	+32·0	+139·0	15†			
3 2 48 30	+32·0	+ 74·0	5	1919 Sept. 5	14	
4 21 54 10	− 9·0	+121·0	*10	1923 Oct. 15	15	
5					9	
6 20 51 32	− 6·0	+160·0	16		8	
7					5	
8 9 43 10	+55·0	− 35·0	14	1924 Mar. 28	10	
9					15	
10 14 57 12	+40·3	+139·5	4	1921 Dec. 12		
10 19 21 50	−27·0	−176·0	12	1923 May 16	11	
11 7 18 14	+42·5	+ 15·5	13	1924 Mar. 26		
11 13 28 20	+49·0	+144·0	22	1924 Mar. 15		
11 17 15 45	+44·5	+140·0	11	1920 Oct. 19	11	
12 19 8 18	+34·0	+139·5	5	1916 Apr. 21		
12 21 50 36	−15·0	+155·0	*12	1922 Apr. 10	9	
13 13 47 55	+ 1·0	+118·0	*52†		9	
14 8 57 12	−18·0	−173·0	18	1921 Nov. 29		
14 16 20 15	+ 6·5	+127·0	*97	1923 Mar. 16	17	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1924 *April*—contd.			
	°	°			
15 12 36 0	+ 6·5	+127·0	7	1924 Apr. 14	
15 12 48 34	+46·2	+ 7·9	26		
15 21 0 0	+ 6·5	+127·0	*15	1924 Apr. 15	27
16 19 14 42	+ 6·5	+127·0	5	1924 Apr. 15	7
17					24
18					16
19					7
20 14 26 54	+14·5	+ 52·0	51		13
21 16 12 25	+35·5	+104·0	19	1920 Dec. 28	
21 20 0 50	+19·0	−100·0	*62	1913 Jan. 15	9
22					20
23					15
24					15
25 10 52 45	+41·0	+ 21·5	5	1921 Oct. 21	
25 12 0 40	+52·8	+155·2	11	1923 Sept. 23	
25 18 4 54	+27·5	+142·0	*28		10
26 20 11 54	+ 6·5	+127·0	*9	1924 Apr. 16	5
27 0 14 4	+44·5	+140·0	4	1924 Apr. 11	9
28 17 34 0	+55·0	− 35·0	13	1924 Apr. 8	
28 20 57 4	−26·5	−179·0	*27		14
29 9 8 50	−58·5	+145·5	6	1923 Oct. 22	
29 9 17 48	+55·0	− 35·0	22	1924 Apr. 28	
29 9 54 6	+55·0	− 35·0	13	1924 Apr. 29	
29 20 51 45	+51·5	+161·5	*43		25
30 3 59 10	−34·0	−175·0	*34		
30 5 7 30	−34·0	−175·0	*31		
30 9 8 20	−34·0	−175·0	13		12
		1924 *May*.			

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1924 *May*—contd.			
	°	°			
24 5 25 34	+17·3	+120·5	*7	1923 July 13	10
25 13 46 40	−19·0	+179·0	15†	1921 Sept. 19	23
26					13
27 2 24 50	− 3·5	+146·5	*21	1924 May 24	
27 10 13 45	+17·5	− 72·5	14		
27 14 32 15	+30·0	+ 85·0	5	1913 Mar. 6	
27 20 9 24	+65·8	+131·0	15		12
28 9 51 48	+48·0	+148·0	*66†	1923 Aug. 17	19
29					8
30 3 47 20	+43·5	+ 17·0	11	1923 Mar. 15	
30 4 22 6	+43·5	+ 17·0	11	1924 May 30	28
31 12 2 30	+36·0	+142·0	*41	1923 Dec. 27	
31 12 27 42	+36·0	+142·0	20	1924 May 31	21
		1924 *June*.			
1 1 39 30	+ 0·5	+126·5	8	1924 May 3	24
2 19 39 10	− 9·5	+108·0	14		21
3 2 41 42	+34·0	+139·5	6	1924 Apr. 12	13
4 16 9 30	+14·5	− 94·0	*27	1921 Jan. 8	23
5					21
6					28
7 19 7 20	−29·0	−112·3	16		11
8					8
9 19 43 42	+11·0	+122·0	*17	1917 Feb. 18	
9 21 34 35	+35·2	+ 33·3	8	1921 Apr. 20	8
10					25
11					11
12 21 3 48	+43·8	+ 11·2	16	1922 Sept. 20	18
13					6

3 11 19 30	+ 0·5	+126·5	*22	1923 Dec. 19	
3 15 14 48	+16·0	+119·0	9		14
4 16 51 40	−22·0	+179·0	*72†		19
5 6 7 45	+15·5	−106·0	8		
5 15 56 45	+12·5	+158·0	*10		14
6 2 49 0	−34·0	−175·0	*22	1924 Apr. 30	
6 6 23 10	+55·0	−160·0	9	1924 Jan. 7	
6 10 32 5	+55·0	−160·0	*10	1924 May 6	
6 16 9 20	+16·0	+119·0	*73	1924 May 3	23
7 0 17 45	−16·0	+140·0	15		33
8 5 35 42	−10·7	+158·5	23		58
9					15
10 2 48 40	−36·3	−169·0	*30		19
11 15 53 10	+34·6	+140·7	21	1921 May 13	
11 22 16 48	+40·0	+ 76·0	5	1924 Mar. 31	13
12 8 45 54	+46·5	+ 13·0	19	1918 Feb. 19	
12 14 30 50	+42·5	+ 26·0	20		19
13 1 52 30	+40·0	+ 42·0	24		
13 19 15 26	+26·3	+121·5	8	1918 Dec. 16	9
14 1 29 20	−50·0	− 24·0	*14†	1923 Oct. 17	10
15 4 22 24	− 1·0	+129·0	8†	1923 Oct. 7	
15 13 57 34	+58·5	+163·0	5†	1923 Oct. 15	14
16 12 50 36	+11·0	+127·0	17†	1923 Oct. 15	
16 18 22 50	+42·0	+ 22·5	20		12
17 3 47 30	−17·0	−177·5	22	1923 Sept. 12	
17 5 16 10	− 1·4	+133·0	*38	1921 Feb. 19	15
18					16
19					11
20 0 59 48	+42·5	+ 7·5	12	1922 May 26	9
21 1 29 6	+33·6	−111·4	8	1923 Nov. 1	
21 10 12 50	+14·5	− 88·7	*18		
21 15 32 36	+47·0	+ 10·0	14	1924 Mar. 26	17
22 17 14 40	−39·0	+166·5	19		
22 18 9 12	+44·0	+141·5	*27		10
23 14 36 40	+28·0	+127·0	18	1922 Feb. 22	
23 21 1 15	+ 9·5	+128·8	*7	1923 July 18	12
24 2 15 30	− 3·5	+146·5	*29	1922 Dec. 14	

16					15
17 16 26 36	+37·5	+ 90·0	8	1923 Nov. 21	
17 20 51 15	+ 1·0	−129·0	8		13
18 17 26 45	+40·0	+ 26·0	15		
18 17 30 52	+33·6	−111·4	8	1924 May 21	5
19					15
20 16 21 28	0·0	− 27·0	*13	1917 Oct. 28	4
21					7
22 13 23 40	+30·6	+144·0	*26	1923 June 29	
22 16 36 48	− 6·5	+107·5	*26†	1921 Mar. 3	
22 22 28 58	+ 5·5	− 77·5	*17		14
23 4 45 16	+ 9·5	+128·8	*10	1924 June 15	5
24 13 48 50	+ 8·0	−118·0	13		18
25					11
26 1 37 20	−57·0	+159·0	*98		
26 3 27 48	+36·0	+142·0	4	1924 May 31	18
27					11
28					22
29					64
30 3 41 12	+27·5	+ 53·8	17	1913 Mar. 24	
30 11 35 16	+49·0	+174·0	16	1923 Aug. 8	
30 15 44 18	+44·7	+147·6	*86†		28
		1924 *July.*			
1 3 1 0	+43·0	−125·0	4	1922 Jan. 26	
1 3 26 6	+43·0	−125·0	13	1924 July 1	
1 6 20 0	+ 1·0	+ 32·0	19		17
2 18 4 40	+14·5	− 94·0	*17	1924 June 4	31
3 4 40 0	+37·3	+ 85·3	*89†		
3 8 8 30	+35·5	+ 55·0	3	1923 Sept. 17	
3 8 18 50	+35·5	+ 55·0	5	1924 July 3	
3 21 31 36	+39·0	+135·5	4		25
4					21
5 15 1 54	+37·3	+ 85·3	22	1924 July 3	
5 22 51 40	+42·0	+142·0	*35	1923 Aug. 14	30
6 14 18 36	+ 7·5	− 79·0	*66	1923 Sept. 9	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	1924 *July*—contd.				
	°	°			
6 18 31 40	+41·0	+ 73·5	*65		29
7 2 39 42	−14·0	−174·0	41	1918 May 2	
7 8 52 45	+25·8	+128·0	*26		
7 11 59 0	+41·0	+ 73·5	11	1924 July 6	
7 17 20 50	−18·5	− 63·5	14	1920 Aug. 13	24
8 9 5 20	+43·5	+139·0	8		
8 10 49 12	+50·0	−170·0	8	1914 Jan. 30	
8 20 43 40	− 9·5	+157·0	23	1920 Jan. 13	19
9 20 24 8	+41·0	+144·0	21	1922 May 15	9
10					17
11 19 44 33	+37·3	+ 85·3	*86	1924 July 5	
11 23 40 30	+36·0	− 19·0	8		10
12 9 4 26	+43·0	+ 93·0	12		
12 10 29 30	+43·0	+ 93·0	7	1924 July 12	
12 15 12 24	+41·0	+ 73·5	*65	1924 July 7	27
13					24
14 2 57 15	+50·4	− 31·6	14	1920 Oct. 16	
14 12 4 24	+26·3	+121·5	6	1924 May 13	21
15 0 10 6	+46·0	− 76·0	8		
15 21 38 0	+37·3	+ 85·3	10	1924 July 11	8
16					26
17 11 42 6	−41·0	− 92·0	*18		14
18					13
19 2 50 7	+72·8	+ 2·5	15	1924 Mar. 12	
19 12 47 45	+34·0	+ 4·0	10	1921 Oct. 22	5
20 0 21 40	+ 7·5	− 79·0	8	1924 July 6	
20 9 17 58	−18·5	+168·5	21	1924 Jan. 25	4
21 0 36 18	+ 2·4	+ 98·8	18	1921 Apr. 1	11
22 4 4 16	− 1·0	− 79·0	*48†		
22 14 23 46	+24·0	+121·0	*56	1922 Oct. 10	33
					12

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	1924 *August*—contd.				
	°	°			
17 10 52 0	−18·0	−173·0	15	1924 Apr. 14	
17 21 39.20	+36·5	+ 16·5	8		16
18					13
19					29
20					10
21 18 50 45	+51·0	−179·5	*25	1923 Nov. 17	20
22					17
23 18 42 46	+36·0	+142·0	7	1924 Aug. 17	17
24					19
25 2 21 40	−45·0	+ 34·0	*53		
25 14 30 48	+36·0	+142·0	*66	1924 Aug. 23	
25 17 16 46	+36·0	+142·0	14	1924 Aug. 25	
25 23 6 54	+55·0	+162·5	*51	1923 Feb. 24	16
26					18
27 22 33 44	+41·5	− 30·5	31		30
28 7 58 22	+ 5·0	+120·0	*6	1923 Aug. 11	
28 18 47 18	+41·5	− 30·5	11	1924 Aug. 27	
28 23 50 36	+34·0	+131·0	*29	1920 May 21	35
29					17
30 3 4 48	+ 8·0	+126·5	*86	1923 Sept. 27	14
31					6
	1924 *September*.				
1					6
2 2 3 0	+23·0	+ 95·0	3	1914 Mar. 28	
2 21 56 30	+ 9·0	+128·0	*15	1923 Aug. 30	
2 23 52 0	+32·2	−110·1	5	1922 Sept. 30	
2 23 57 40	+32·2	−110·1	11	1924 Sept. 2	12
3 2 29 0	+17·5	− 47·5	*8	1919 Oct. 8	16
4 1 6 0	+17·5	− 47·5	11	1924 Sept. 3	

24	4	55	24	−48·0	+159·0	*70		23
25	19	36	18	+72·5	+ 16·0	13		
25	21	39	24	+38·0	+ 43·0	5		12
26	3	0	0	+ 6·5	+128·0	*11	1923 May 25	12
27								15
28								18
29	5	18	40	− 2·5	+121·0	*48	1924 Feb. 13	10
30								11
31	13	13	42	+40·0	+ 37·0	7	1923 Apr. 29	13
				1924 *August.*				
1	0	56	0	+55·7	+162·5	12	1923 Apr. 13	
1	14	42	56	+26·0	+ 96·0	8	1924 Feb. 14	16
2								22
3								13
4								6
5	1	26	45	+32·0	− 37·5	16		7
6	0	22	0	−28·0	−163·5	25	1923 July 4	
6	14	22	18	+38·5	+146·0	*21	1919 Aug. 7	16
7								31
8	22	10	30	+34·0	+ 21·0	7	1920 May 19	18
9								9
10	6	11	54	−30·2	−179·0	*55	1923 June 2	9
11	2	25	42	+82·0	+120·0	10		11
12	16	27	37	+45·0	+ 22·0	18	1922 Mar. 24	
12	18	18	37	+32·2	+134·6	*15	1913 Apr. 13	12
13	9	28	24	−16·0	+168·0	15	1923 Nov. 10	
13	13	30	19	+52·0	−178·0	*39	1919 July 14	
13	23	57	42	+29·5	+ 91·5	32	1915 Dec. 3	27
14	0	45	24	+51·5	−162·5	*26		
14	17	53	36	+36·0	+142·0	*9	1924 June 26	
14	18	2	33	+36·0	+142·0	*86	1924 Aug. 14	
14	23	27	24	+36·0	+142·0	*54	1924 Aug. 14	17
15								21
16								31
17	1	45	54	+36·0	+142·0	*55	1924 Aug. 14	
17	2	10	0	+36·0	+142·0	*49	1924 Aug. 17	

4	1	14	0	− 6·0	+105·0	2	1924 Mar. 18	
4	6	24	5	+36·0	+142·0	6	1924 Aug. 25	
4	16	1	0	+64·0	− 25·0	35		25
5	14	47	36	+ 9·0	+128·0	*14	1924 Sept. 2	13
6	2	36	55	+46·5	+160·0	*17	1916 Oct. 31	
6	4	50	56	+40·0	+ 42·0	25	1924 May 13	
6	19	37	10	− 8·4	+155·8	*33	1920 May 7	23
7	1	45	40	+ 9·0	+128·0	*19	1924 Sept. 5	
7	6	14	25	+82·0	+ 10·0	11		
7	7	59	0	−18·0	+173·5	14	1921 Nov. 14	
7	13	31	0	+40·5	−122·0	7	1923 Apr. 29	
7	14	11	30	+ 9·0	+128·0	7	1924 Sept. 7	
7	18	48	0	−18·0	+173·5	21	1924 Sept. 7	11
8	9	4	11	+56·8	− 33·6	3	1921 Aug. 23	
8	9	41	20	+56·8	− 33·6	12	1924 Sept. 8	
8	10	16	48	+56·8	− 33·6	3	1924 Sept. 8	
8	10	42	10	+56·8	− 33·6	3	1924 Sept. 8	
8	11	48	50	+56·8	− 33·6	3	1924 Sept. 8	11
9	0	27	25	+19·4	− 99·2	6		
9	10	2	0	+40·5	−122·0	5	1924 Sept. 7	
9	14	41	50	+ 9·0	+128·0	7	1924 Sept. 7	17
10	4	43	10	+ 9·0	+128·0	8	1924 Sept. 9	
10	5	54	18	− 7·0	+124·0	*14†	1923 Mar. 28	
10	11	59	10	+37·0	+ 34·3	26		9
11	3	25	40	+ 4·8	+126·0	*47	(1918 Feb. 27)	10
12	0	9	40	+33·2	+ 71·4	5		
12	8	59	30	+33·2	+ 71·4	6	1924 Sept. 12	9
13	14	34	0	+40·0	+ 42·0	*85	1924 Sept. 6	
13	15	37	20	+40·0	+ 42·0	6	1924 Sept. 13	
13	16	3	39	+40·0	+ 42·0	1	1924 Sept. 13	
13	16	22	21	+40·0	+ 42·0	1	1924 Sept. 13	
13	16	31	57	+40·0	+ 42·0	1	1924 Sept. 13	
13	17	6	47	+40·0	+ 42·0	3	1924 Sept. 13	
13	17	20	10	+40·0	+ 42·0	1	1924 Sept. 13	
13	17	41	14	+40·0	+ 42·0	1	1924 Sept. 13	
13	17	47	41	+40·0	+ 42·0	2	1924 Sept. 13	
13	19	12	24	+ 9·0	+128·0	*20	1924 Sept. 10	
13	19	49	33	+40·0	+ 42·0	1	1924 Sept. 13	

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	1924 *September*—contd.				
	°	°			
13 20 45 0	+40·0	+ 42·0	14	1924 Sept. 13	
13 21 44 0	+40·0	+ 42·0	1	1924 Sept. 13	
13 22 44 50	+40·0	+ 42·0	1	1924 Sept. 13	
13 23 3 40	+40·0	+ 42·0	9	1924 Sept. 13	22
14 0 49 31	+40·0	+ 42·0	1	1924 Sept. 13	
14 4 32 30	+36·0	+142·0	9	1924 Sept. 4	
14 4 59 28	+36·0	+142·0	7	1924 Sept. 14	
14 8 39 48	+36·0	+142·0	2	1924 Sept. 14	
14 10 40 18	+36·0	+142·0	9	1924 Sept. 14	
14 13 12 52	+50·1	+178·7	*57	(1923 Nov. 17)	
14 14 8 0	+ 9·0	+128·0	*43	1924 Sept. 13	
14 17 37 56	+40·0	+ 42·0	1	1924 Sept. 14	39
15 12 9 45	+40·0	+ 42·0	1	1924 Sept. 14	
15 20 6 40	+45·0	+ 11·5	7	1921 Sept. 12	15
16 2 35 54	+38·8	+ 70·0	49		
16 21 37 36	+40·0	+ 42·0	4	1924 Sept. 15	17
17 7 4 10	+19·0	− 70·0	10	1920 Nov. 6	
17 10 20 30	+37·5	+ 70·5	14	1923 July 29	
17 16 45 25	+49·0	+174·0	6	1924 June 30	14
18 1 8 40	+37·5	+140·0	*28	1922 Jan. 22	
18 2 53 54	+37·5	+140·0	8	1924 Sept. 18	13
19 0 32 6	−35·0	− 75·0	3		
19 6 49 30	−21·5	−171·5	16	1918 Feb. 25	25
20 16 52 15	+ 9·0	+128·0	4	1924 Sept. 14	13
21 15 8 20	+ 9·0	+128·0	2	1924 Sept. 20	
21 20 17 35	+45·0	+ 11·5	5	1924 Sept. 15	23
22 2 0 30	+ 9·0	+128·0	4	1924 Sept. 21	
22 7 42 40	+40·0	+ 42·0	2	1924 Sept. 16	
22 22 4 0	+36·0	− 5·0	7	1923 Oct. 19	16
23 23 2 50	+40·0	+ 42·0	8	1924 Sept. 22	12
[illegible]	+37·5	+140·0	27	1924 Sept. 18	

d. h. m. s.	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
	1924 *October*—contd.				
	°	°			
19 23 52 10	+27·0	− 42·0	26	1922 Sept. 22	10
20 5 21 25	+39·7	−124·6	5	1923 Jan. 22	
20 8 38 20	−27·6	− 66·3	16	1920 Aug. 3	
20 19 52 42	+55·2	+165·0	*76		14
21					24
22					12
23 12 47 40	+36·5	+139·5	5	1922 May 9	
23 21 35 40	+50·0	+149·0	11		20
24					22
25 19 9 14	+30·0	− 28·0	17		14
26 18 20 28	+ 7·0	+126·0	*11		3
27 19 56 52	+ 7·0	+126·0	*46	1924 Oct. 26	
27 20 48 48	+ 7·0	+126·0	5	1924 Oct. 27	10
28					7
29					5
30					14
31 2 58 40	− 6·5	+126·0	*12	1924 Sept. 10	10
	1924 *November*.				
1 4 55 15	+ 9·5	− 84·0	25	1924 Mar. 28	21
2 11 25 0	+24·0	+120·0	7	1923 Dec. 4	10
3 19 0 45	− 8·5	+ 67·0	8	1922 July 3	8
4 3 2 45	−49·0	−132·0	14	1922 Feb. 2	11
5 8 30 50	−19·0	−173·0	21	1922 Dec. 23	
5 18 54 20	+35·3	+ 3·5	26		25
6 7 46 0	+35·7	+ 81·0	7	1920 Oct. 12	
6 17 57 40	+35·3	+ 3·5	4	1924 Nov. 5	
6 18 40 20	+35·3	+ 3·5	3	1924 Nov. 6	
6 22 59 45	+35·3	+ 3·5	12	1924 Nov. 6	36
7 10 54 20	+47·0	+ 10·0	4	1924 May 21	18

24 [illegible]	+32·0	+ 10·0	2	1924 Sept. 7	12
25 4 1 15	−48·5	−160·5	16	1920 Feb. 19	15
26					15
27 3 58 0	+ 9·0	+128·0	18	1924 Sept. 22	
27 4 27 23	+40·0	+ 42·0	25	1924 Sept. 23	
27 10 12 10	+37·0	+ 53·0	3		
27 12 46 40	−35·0	+111·0	12	1920 Feb. 8	21
28 13 34 4	+46·5	− 28·3	34	1923 Sept. 11	15
29					6
30 8 54 0	+43·4	− 72·0	9	1918 Sept. 12	12

1924 *October.*

1					9
2 16 31 48	+37·0	+138·5	4	1923 Jan. 14	14
3					11
4 6 41 6	+15·0	+ 44·0	6		3
5 12 56 6	−20·6	+168·8	19	1921 Dec. 2	
5 13 21 30	+35·5	+141·0	5	1923 Nov. 21	14
6 6 22 30	−12·2	+118·0	6	1921 Jan. 24	15
7					11
8 20 32 52	+30·5	+ 91·0	*67†	1921 Oct. 14	14
9					9
10 9 21 4	+71·7	− 17·0	15		
10 16 5 20	+71·7	− 17·0	8	1924 Oct. 10	12
11					15
12 19 34 0	− 1·2	− 29·6	*53		7
13 8 7 42	+38·0	+ 23·7	5	1923 Sept. 19	
13 12 25 25	−24·0	− 24·0	*21		
13 16 17 36	+37·0	+ 72·0	*61†	1915 June 3	9
14 5 0 6	+24·0	− 46·0	53	1922 Sept. 8	14
15 4 15 42	+37·0	− 10·0	6	1922 Oct. 20	9
16					15
17 4 23 10	+60·0	−118·0	20		12
18 19 35 52	+29·0	+130·0	26	1923 Nov. 6	
18 22 47 30	+37·2	− 3·6	11		
18 23 5 15	+ 3·0	− 80·5	*44		21
19 15 34 45	+79·0	+110·0	20		

8 [illegible]	+35·5	+ 48·0	20		
8 17 45 20	+35·5	+ 48·0	3	1924 Nov. 8	23
9 1 13 35	+52·0	+103·0	5		
9 12 48 20	+52·5	+157·5	5	1922 Aug. 16	29
10 21 8 56	+35·5	+ 48·0	4	1924 Nov. 8	
10 21 54 56	+35·5	+ 48·0	8	1924 Nov. 10	11
11 15 53 40	+35·5	+ 48·0	3	1924 Nov. 10	18
12 6 24 10	− 5·0	+109·0	3		
12 9 28 20	+35·5	+ 48·0	3	1924 Nov. 11	15
13 8 32 0	−27·0	−176·0	*31	1924 Apr. 10	
13 9 44 0	+40·0	+ 20·0	25	1923 Oct. 30	15
14					9
15					17
16 23 14 30	+17·5	− 47·5	*10	1924 Sept. 4	15
17					2
18 11 39 0	− 2·0	+128·5	10	1921 May 20	
18 12 5 0	− 2·0	+128·5	*9	1924 Nov. 18	11
19					21
20 20 27 38	+39·0	+ 31·0	*58		10
21					6
22					8
23					14
24 7 58 48	− 7·5	+110·0	*14		16
25 17 26 40	+45·0	+138·0	20		8
26 6 50 35	+ 2·0	− 20·5	*5	1921 Dec. 21	9
27					12
28 12 9 35	+55·0	+176·0	9		
28 12 36 20	+55·0	+176·0	14	1924 Nov. 28	
28 19 2 15	+55·0	+176·0	*18	1924 Nov. 28	
28 21 50	?	?	16		
28 22 57 10	+37·2	− 3·6	3	1924 Oct. 18	18
29					4
30					10

1924 *December.*

1 6 2 18	+ 7·0	+126·0	*11	1924 Oct. 27	
1 22 56 48	−12·0	−177·0	16		12

CATALOGUE OF EARTHQUAKES, 1918–1924—*contd.*

1924 *December*—contd.

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
2					16
3 21 34 45	+45·0	+ 16·0	14	1924 Jan. 29	16
4					8
5 9 36 12	+ 3·0	+125·0	*24		9
6					18
7 15 43 15	+46·5	− 28·3	16	1924 Sept. 28	3
8					19
9 11 53 0	−10·2	+143·4	*19	1920 Apr. 2	
9 16 21 45	−10·2	+143·4	*10	1924 Dec. 9	9
10					4
11 16 33 15	+48·0	+ 8·0	11		
11 17 28 24	−41·5	+ 80·0	*38		
11 21 25 35	+39·0	0·0	5	1922 Sept. 15	
11 23 1 0	+25·2	+ 56·8	11		17
12 2 20 45	+56·8	− 33·6	17	1924 Sept. 8	
12 3 28 42	+46·5	+ 13·0	25	1924 May 12	
12 7 20 54	+48·0	+ 8·0	8	1924 Dec. 11	
12 8 47 30	−40·0	−120·0	14		
12 23 44 50	−11·5	+112·0	*22	1921 Sept. 11	24
13 18 53 30	+38·0	+ 33·5	9	1922 Aug. 29	
13 20 24 32	+36·5	+138·5	9		13
14 9 6 20	+82·0	− 38·0	13		
14 9 23 36	+82·0	− 38·0	8	1924 Dec. 14	

1924 *December*—contd.

d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
14 21 10 0	−33·0	− 66·0	4		3
15 20 48 50	−15·7	+167·3	*39	1921 July 31	4
16					18
17					33
18 15 24 40	−28·5	− 71·5	6	1923 Aug. 7	6
19					10
20					6
21 12 58 42	+34·5	+138·0	5	1920 June 22	13
22 6 50 40	+45·0	+ 11·0	14	1923 June 28	
22 17 49 42	+39·6	+ 27·7	10	1919 Nov. 18	5
23 17 4 50	+41·0	+ 24·6	23	1921 May 10	22
24 17 1 36	+19·0	+120·5	*9	1922 Oct. 14	
24 22 3 30	−21·5	−179·0	24		4
25 17 53 0	+36·0	− 5·0	4	1924 Sept. 22	10
26 23 31 20	−17·0	−168·0	*24†	1922 Feb. 20	
26 23 32 43	−32·0	−173·0	5†		
26 23 40 30	+14·0	+109·0	*12†		18
27 11 22 0	+45·0	+143·0	*64†		11
28 22 54 52	+43·2	+147·2	*84		9
29 1 11 0	+43·2	+147·2	6	1924 Dec. 28	8
30					37
31 4 40 30	+51·0	+141·0	3	1922 Jan. 24	19

Notes to 1918.

Jan. 15d. 15h. Subsequent shock at 15.57.34, recorded at Taihoku and Zikawei.

Jan. 30d. 21h. Focal depth +0·050. Epicentre revised from 47·5° N. 129·0° E. originally adopted. See p. 219 in Summary.

Feb. 7d. 5h. Focal depth +0·025.

Feb. 9d. 20h. Focal depth +0·050. Epicentre revised from 25·6° N. 134·1° E. See p. 219 in Summary.

Mar. 23d. 0h. The epicentre 49·0° N. 144·0° E. is not satisfactory, but it is far from clear what can be substituted. The best supposition is 42·0° N. 131·0° E. See p. 219 in Summary.

April 10d. 2h. Focal depth +0·065. Epicentre recorded from 44·0° N. 131·0° E. with 0·070 focus originally given.

May 20d. 17h. (?) Deep focus ; evidence scarcely sufficient.

May 22d. 6h. Focal depth +0·050.

May 23d. 11h. Focal depth +0·010. Epicentre revised from 27·0° N. 109·5° W.

May 25d. 19h. Focal depth +0·015.

June 21d. 3h. Defective solution. See note in Summary.

June 24d. 14h. (?) *High* focus and epicentre at 1·0° S. 154·0° E. as on 1914 May 18–19.

July 8d. 10h. Focal *height* −0·010. Long note in Summary.

Aug. 8d. 9h. Longitude given in Summary incorrectly as 153·4° E.

Aug. 11d. 23h. First of a series of 12 shocks. See note in Summary.

Aug. 22d. 8h. See note in Summary.

Sept. 7d. 17h. Focal *height* −0·030.

Sept. 8d. 0h. Focal *height* −0·030.

Sept. 8d. 5h. Normal *height*. See note in Summary.

Sept. 12d. 13h. Focal *height* −0·030.

Nov. 23d. 22h. Focal depth +0·030.

Dec. 14d. 18h. Focal depth +0·030.

Dec. 25d. 10h. Focal depth +0·070.

Notes to 1919.

Jan. 1d. 3h. Focal depth +0·030.

Mar. 1d. 13h. Focal depth +0·030.

Mar. 2d. 3h.
2d. 11h.
9d. 3h. Discussion of residuals suggests focal depth +0·020 and revised epicentre −43·7° −77·0°.

Mar. 16d. 7h.
16d. 15h. Focal depth +0·015.

Mar. 30d. 10h. Focal depth +0·030.

Apr. 17d. 20h. Focal depth +0·010.

Apr. 30d. 7h. Evidence in favour of a *high* focus.

May 3d. 0h. Focal depth +0·005.

May 6d. 19h. Focal *height* −0·030, after careful discussion. Many antipodal observations support this view.

May 20d. 4h. The observations of the two shocks are difficult to separate.

May 29d. 10h. Focal *height* −0·020.

June 1d. 6h. Focal depth +0·040.

July 25d. 3h. Identification of epicentre doubtful.

Aug. 9d. 14h. Identification of epicentre doubtful.

Aug. 18d. 16h.
18d. 20h. Focal depth +0·050.

Aug. 31d. 17h. Focal depth +0·015. Revised solution. In the first instance 15·0° S. 165·0° E., as on 1919 Aug. 29, was adopted, with normal focal depth, but found unsatisfactory.

Sept. 10d.–16d. A rather remarkable series of shocks.

Oct. 12d. 21h. Study of the residuals suggests a *high* focus (−0·020 say) with epicentre 2·0° S. 102·5° E.

Oct. 27d. 3h. Focal depth +0·040.

Nov. 6d. 7h. Focal depth +0·010.

Nov. 20d. 14h. Focal depth +0·040.

Notes to 1920.

Jan. 20d. 1h. Focal depth +0·030.
Feb. 22d. 17h. Focal depth +0·050.
Feb. 26d. 1h. Focal depth +0·050.
Mar. 3d. 10h. Focal depth +0·030.
Mar. 15d. 12h. Focal depth +0·030.
Mar. 22d. 20h. Focal depth +0·040.
Apr. 6d. 19h. Focal depth +0·050.
May 6d. 9h. Focal depth +0·070.
May 10d. 18h. Focal depth +0·060.
May 27d. 5h. Focal depth +0·050. An alternative solution is given with normal focus at 19·0° N. 109·0° E.
May 30d. 20h. The latitude of the epicentre is wrongly given in the Summary as 32·0° N. instead of 32·2° N. which corresponds to the constants used.
July 2d. 18h. Focal depth +0·070.
July 20d. 12h. Focal depth +0·010.
July 26d. 5h. Deep focus suggested, but evidence insufficient.
Aug. 3d. 3h. Focal depth +0·040.
Aug. 15d. 8h. Focal depth +0·030.
Nov. 24d. 11h. Focal depth +0·010.
Dec. 16d. 12h. The terribly disastrous earthquake in Kansu.
Dec. 18d. 10h. Focal depth +0·020.

Notes to 1921.

Mar. 4d. 12h. Focal depth +0·060.
Mar. 6d. 7h. Focal *height* −0·020.
Mar. 23d. 22h. Focal depth +0·060. Revised from solution with normal focal depth at 8·0° S. 127·5° E.
Mar. 24d. 1h. Focal depth +0·060. Revised from solution with normal focal depth at 6·5° S. 131·5° E.
Mar. 30d. 15h. 2m. Focal depth +0·040.
Apr. 15d. 21h. *High* focus suggested, but evidence insufficient.
Apr. 25d. 17h. Focal depth +0·040. Compare 1917 May 24.
May 12d. 3h. Two antipodal observations suggest a *high* focus, but those near epicentre do not support this ; indeed, they suggest a deep focus.
May 20d. 0h. Focal depth +0·030.
May 20d. 13h. *High* focus suggested, but evidence insufficient.
July 4d. 14h. 18m. +25·0° +141·5°. Would perhaps be better with focal depth +0·030, T_0=14h. 18m. 20s., and an epicentre further to the N.W.
July 4d. 14h. 18m. +29·0° +130·0°. Curiously close in time to (represented as simultaneous with) above shock.
July 14d. Only one tremor recorded all day, at 7h., near Nagasaki.
July 15d. 18h. Focal depth +0·030.
Sept. 20d. 20h. Residuals not good. Possibly two shocks. Or focal depth +0·050, with epicentre 1·5° S. 109·3° E.
Oct. 10d. 2h. Focal depth +0·060.
Nov. 15d. 20h. Focal depth +0·030.
Dec. 18d. 15h. Focal depth +0·080 ; exceptionally deep.

Notes to 1922.

Jan. 17d. 3h. Focal depth +0·070.
Feb. 5d. 3h. Focal *height* −0·040.
Mar. 4d. 13h. Focal depth +0·030.
Mar. 6d. 21h. Focal depth +0·030.
Mar. 10d. 16h. Focal depth +0·060.
Mar. 28d. 3h. Focal depth +0·010.
July 10d. 9h. Focal depth +0·050.
Aug. 3d. 9h. Focal depth +0·020.
Aug. 13d. 0h. and 13d. 12h. In the Summary a discussion of the residuals for these two shocks and for that of August 11d. suggests that the epicentres are closely the same within a small fraction of 1°.

Aug. 14d. 11h. Focal depth $+0{\cdot}010$.

Sept. 1d. 19h. The first of a series of shocks in North Formosa, others following on Sept. 14, 15, 16, 17, Oct. 14, Dec. 1 and 12, in which 50 people were killed and 1,000 houses damaged or destroyed.

Sept. 4d. 17h. Focal depth $+0{\cdot}080$ (exceptionally deep).

Sept. 22d. 21h. On the evidence of the La Paz observations the epicentre may be at 25·2° N. 46·6° W. with a focal depth $+0{\cdot}045$.

Oct. 11d. 14h. The S residuals of this earthquake near $\Delta=90°$ were seen to be consistently negative with a difference from the tables for S approximately linear in Δ. Almost simultaneously a letter from Dr. Harold Jeffreys drew attention to Gutenberg's suggestion (in 1914) of an S_cP_cS wave, which traverses the earth's central core as P, and was readily identified with the phenomenon thus noticed, which has since been denoted by [S]. The anomaly had already been noticed in discussing the *Large Earthquakes of* 1913: *B.A. Seism. Ctee.*, 1917., but the proper explanation of it was first noticed on this occasion (*i.e.* in 1926, twelve years after Gutenberg's paper).

Oct. 17d. 6h. Possibly 18·0° N. 97·0° E. as on 1919 Sept. 8, but with focal *height* $-0{\cdot}030$.

Oct. 24d. 21h. Focal depth $+0{\cdot}010$.

Nov. 3d. 12h. Focal depth $+0{\cdot}040$.

Nov. 11d. 4h. A disastrous earthquake felt over the whole of Chile, 'between Antofogasta (lat. $-23°$) in the north and Valdivia (lat. $-40°$) more than a thousand miles to the south of it' (London *Times* of November 13), 1,800 killed, 35,000 homeless, &c. An investigation by Prof. Bailly Willis suggested an origin 'near the solitary islands of St. Felix and St. Ambrose' (say 26·5° S. 80·0° W.), where all the lobsters were killed; but it seems improbable that the origin could be so far west. There are many observations of [S], not, however, identified as such in the Summary.

Dec. 6d. 13h. Focal depth $+0{\cdot}020$.

Dec. 19d. 3h. The La Paz observations are inconsistent with those at Mendoza and the former has been preferred. If the latter is preferred, a solution would be Dec. 19d. 2h. 59m. 20s. Epicentre 32·9° S. 68·3° W.

Notes to 1923.

Jan. 14d. 5h. The macroseismic observations were carefully discussed by Omori who arrived at the position 36° 4′ N. 140° 3′ E. for the epicentre; but this does not fit the seismographic results. The earthquake is noteworthy as having occasioned Omori's prediction that 'Tokyo may be assumed to be free in future from the visitation of a violent earthquake like that of 1855 . . . as destructive earthquakes do not repeat from one and the same origin, at least not in the course of 1,000 or 1,500 years.' The terrible falsification of this hopeful forecast on September 1, 1923, is now matter of history.

Jan. 22d. 9h. Berkeley gave 41·1° N. 125·5° W., but this does not fit the observations as fully shown in the Summary.

Feb. 2d. 1h. and 2d. 5h. The residuals for these two shocks are directly compared in the Summary and found to be larger than usual; but the differences appear to be accidental rather than systematic.

Feb. 19d. 6h. Focal depth $+0{\cdot}060$.

Feb. 24d. 7h. The residuals are divisible into two groups, but no explanation of the difference can be assigned with confidence. The best that suggests itself is

A shock at 7h. 34m. 52s. at focal *depth* $+0{\cdot}020$;

A shock at 7h. 34m. 15s. at focal *height* $-0{\cdot}020$;

the epicentre being the same in the two cases.

Mar. 2d. 16h. In the Summary a previous shock from this epicentre on 1922 June 27 is erroneously noted. The epicentre on that date is 6·5° N. 126·0° E.

Mar. 4d. 0h. Perhaps the most puzzling case in our experience. It seems impossible to suggest any solution which does not imply several errors in the observations. A possible alternative is Mar. 4d. 0h. 7m. 5s. Epicentre 16·0° S. 1·0° E.

Mar. 28d. 20h. On previous occasions a deep focus has been assumed, and the same assumption would suit this case also, but the observations are too few to warrant it.

April 23d. 3h. Focal *height* $-0{\cdot}030$. Revised from solution with normal focal depth and epicentre 29·0° N. 124·5° E.

May 11d. 8h. In the Summary the longitude of epicentre is erroneously given as 116·5° E.

June 29d. 10h. Alternatives with focal depth +0·060 and epicentre *either* 30·6° N. 144·0° E. *or* 27·3° N. 138·5° E. are suggested ; but the material is scanty.

July 22d. 12h. Possible alternative epicentre (assuming errors of 1m. at Athens and 4m. at Budapest), 40·5° N., 25·5° E. (as on 1918 April 17d.).

Aug. 8d. 12h. Focal depth +0·025.

Aug. 12d. 5h. Possible alternative supposition of two shocks at 6h. 3m. 24s. and 6h. 10m. 13s. from epicentre 35·0° N. 143·0° E. (as on 1922 March 16d.), recorded by Osaka as separate phases of a more distant disturbance.

Aug. 31d. 11h. The previous occurrence is erroneously given in the Summary as on 1919 Jan. 1d.

Sept. 1d. 2h. The first of the disastrous shocks which destroyed Tokio and Yokohama.

Sept. 2d. 2h., 2d. 9h. 26m., 2d. 13h. 9m., 2d. 14h. 16m. Focal depth +0·010.

Sept. 9d. 4h. Alternative solution, 9d. 4h. 18m. 10s. from epicentre 7·5° N. 79·0° W. (as on 1922 May 22d.), or perhaps two shocks as follows :—

9d. 4h. 16m. 25s. from epicentre 0·0° 75·0° W.

9d. 17h. 11m. 0s. from epicentre 35·0° N. 139·5° E.

Oct. 15d. 7h. Suggested revised solution with focal depth +0·020 below normal :

Oct. 15d. 7h. 32m. 18s. }
15d. 7h. 58m. 25s. } Epicentre 8·0° S. 123·5° E.

on the assumption that Batavia and Malabar are 1m. in error.

Nov. 3d. 8h. Focal depth +0·010.

Nov. 17d. 2h. Focal depth +0·020.

Dec. 19d. 19h. Focal depth +0·010.

Dec. 28d. 22h. Focal depth +0·010.

Notes to 1924.

Jan. 16d. 21h. Focal depth +0·030.

Feb. 24d. 16h. Focal depth +0·030.

Mar. 5d. 4h. Focal depth +0·030.

Mar. 25d. 21h. Focal depth +0·060.

April 3d. 2h. Focal depth +0·050.

April 13d. 13h. Focal depth +0·015.

May 4d. 16h. Focal depth +0·060.

May 14d.–16d. It is curious that four shocks from widely different epicentres should be repeated from 1923 Oct. 7–17.

May 25d. 13h. Focal depth +0·070.

May 28d. 9h. Focal depth +0·060.

June 22d. 16h. Focal depth +0·020.

June 30d. 15h. Focal depth +0·020.

July 3d. 4h. The corrections to S near $\Delta = 35°$ are small (in other cases they are large).

July 22d. 4h. Focal depth +0·040.

Sept. 10d. 5h. Focal depth +0·040.

Oct. 8d. 20h. Focal depth +0·010.

Oct. 13d. 16h. Focal depth +0·030.

Dec. 26d. 23h. The disentanglement of these three shocks is, of course, subject to much uncertainty.

Dec. 27d. 11h. Focal depth +0·010.

Calculation of Mathematical Tables.—*Report of Committee* (Prof. J. W. NICHOLSON, *Chairman*; Dr. J. R. AIREY, *Secretary*; Dr. D. WRINCH-NICHOLSON, Mr. T. W. CHAUNDY, Dr. A. T. DOODSON, Prof. L. N. G. FILON, Drs. R. A. FISHER *and* J. HENDERSON; Profs. E. W. HOBSON, ALFRED LODGE, A. E. H. LOVE *and* H. M. MACDONALD).

DURING the past year most of the tables referred to in the Report for the Leeds meeting have been completed and now appear in the present Report; tables of the Zonal Harmonics $P_n(\cos\theta)$ and $\frac{\delta P_n(\cos\theta)}{\delta\theta}$ to ten places of decimals for various values of n and θ will be ready for publication next year. Professor A. Lodge has computed tables of $P_n(\cos\theta)$ to seven places of decimals for $\theta=0^\circ$ to 90° by 5° intervals and $n=0$ to 20. (*Phil. Trans.* 203, A. 1904.)

Tables of functions are set out in this Report as follows:

(*a*) Sines and cosines of angles in circular measure to fifteen places of decimals for $\theta=20{\cdot}0$ to $40{\cdot}0$ radians by 0·2 intervals.

(*b*) Hyperbolic sines and cosines, $\sinh \pi x$ and $\cosh \pi x$, for $x=0{\cdot}00$ to $4{\cdot}00$ by 0·01 intervals to fifteen places.

(*c*) Sine and Cosine integrals, $\mathrm{Si}(x)$ and $\mathrm{Ci}(x)$ x ranging from 20·0 to 40·0 by 0·2 intervals to ten places.

(*d*) Bessel Function Derivatives $\frac{\delta}{\delta\nu}\cdot J\nu(x)$ where $\nu=\pm\frac{1}{2}\cdot\pm\frac{3}{2}$, x from 0·0 to 20·0 by 0·1 intervals to six places.

(*e*) Probability Integral $\int_x^\infty e^{-\frac{1}{2}t^2}\cdot dt$ and other functions of higher order derived by repeated integration, for both positive and negative values of the argument, x from 0·0 to $\pm 7{\cdot}0$ and various values of the order, to ten places. Dr. Fisher has called attention to the importance of these functions and also suggested the desirability of including tables in the Report of the Committee.

For next year's Report, in addition to the tables of Zonal Harmonics of high order with the first derivatives, it is proposed to publish further tables of the Confluent Hypergeometric function $M(\alpha\,.\,\gamma\,.\,x)$, Bessel functions of fractional order, extended tables of the Bessel functions $Vr(x)$ and $Vu(x)$ and their first ten zeros [Report, 1916, pp. 52, 57, 62; Table VII computed by Mr. H. G. Savidge], and Elliptic θ functions with both real and imaginary arguments. Professor A. Lodge has computed tables of the series

$$\left(1-\frac{1}{n+1}\right)+\left(\frac{1}{2}-\frac{1}{n+2}\right)+\left(\frac{1}{3}-\frac{1}{n+3}\right)+\ldots.$$

and has kindly offered these to the Committee for publication. The entries are to seven places for $n=0$ to $n=50$· at intervals of 0·1 and to ten places, with first and second differences, for $n=50$ to $n=51$ at intervals of 0·01.

The publication of Mathematical Tables in book form has been under consideration during the past year or two, and some progress has been made in the preparation and arrangement of the tables which have appeared in past Reports of the Committee: tables from other sources may be included, *e.g.* Meissel's tables of Bessel functions of zero and unit order, $J_0(x)$ and $J_1(x)$, etc. It is recommended that the format of all the tables in the volume should be uniform. As the Committee's activities have extended over a period of more than thirty years, the lack of uniformity in the printing and arrangement of the tables is easily understood.

SINES AND COSINES (θ IN RADIANS).

Tables of these ratios have already appeared in Reports of the Committee, viz.: Sin θ and Cos θ, θ from 0·000 to 1·600 by 0·001 intervals with subsidiary tables to ten places, and θ from 0·0 to 10·0 by intervals of 0·1 to fifteen places (1916 Report), Sin θ and Cos θ, θ from 1 to 100 radians to fifteen places (1923 Report), θ from 10·0 to 20·0 radians by 0·1 intervals and from 20·0 to 50·0 radians by 0·5 intervals to fifteen places (1924 Report).

The values of sin θ and cos θ for θ from 20·0 to 40·0 radians by 0·2 intervals were required in the computation of the Sine and Cosine Integrals, Si (x) and Ci (x) over this range of the argument. The tables were calculated from the formulæ for Sin $(x \pm \alpha)$ and Cos $(x \pm \alpha)$. By this means it was possible to check the results for a particular value of the argument from those previously obtained. All the calculations were carried to eighteen places of decimals: in very rare cases will the error in the fifteenth place exceed half a unit.

Sines and Cosines (θ in radians)—*contd.*

θ	Sin θ	Cos θ
20·0	+0·91294 52507 27628	+0·40808 20618 13392
20·2	+0·97582 05177 66976	+0·21857 33677 85262
20·4	+0·99979 29001 42669	+0·02035 08433 31682
20·6	+0·98390 66946 18616	−0·17868 30050 24733
20·8	+0·92879 52340 77241	−0·37059 33258 37641
21·0	+0·83665 56385 36056	−0·54772 92602 24268
21·2	+0·71116 12229 05982	−0·70302 89574 65387
21·4	+0·55731 50535 17660	−0·83030 11087 08526
21·6	+0·38125 04916 54941	−0·92447 17749 14121
21·8	+0·18998 66757 95438	−0·98178 66687 93277
22·0	−0·00885 13092 90404	−0·99996 08263 94637
22·2	−0·20733 64206 06759	−0·97826 97014 06507
22·4	−0·39755 56831 21434	−0·91757 80505 31861
22·6	−0·57192 56551 09563	−0·82030 54583 67490
22·8	−0·72349 47560 44244	−0·69032 98762 01573
23·0	−0·84622 04041 75171	−0·53283 30203 33398
23·2	−0·93520 99151 94539	−0·35409 37933 96358
23·4	−0·98691 55581 20649	−0·16123 79643 24187
23·6	−0·99927 59921 36628	+0·03804 59135 69769
23·8	−0·97179 84457 43863	+0·23581 30209 50522
24·0	−0·90557 83620 06624	+0·42417 90073 36997
24·2	−0·80325 57266 93954	+0·59563 43152 75209
24·4	−0·66890 98203 78023	+0·74334 35626 96174
24·6	−0·50789 65903 90623	+0·86141 80480 28702
24·8	−0·32663 51261 04723	+0·94515 05141 48171
25·0	−0·13235 17500 97773	+0·99120 28118 63474
25·2	+0·06720 80725 25476	+0·99773 89813 91130
25·4	+0·26408 85213 84471	+0·96449 84462 78149
25·6	+0·45044 05942 75388	+0·89280 64017 62910
25·8	+0·61883 50221 20039	+0·78552 09834 22907
26·0	+0·76255 84504 79603	+0·64691 93223 28640
26·2	+0·87588 10798 10890	+0·48252 70293 25104
26·4	+0·95428 50944 92697	+0·29889 79063 64470
26·6	+0·99464 47738 77838	+0·10335 26671 03972
26·8	+0·99535 11049 11559	−0·09631 29168 45760
27·0	+0·95637 59284 04503	−0·29213 88087 33836
27·2	+0·87927 30616 50724	−0·47631 80482 15016
27·4	+0·76711 63526 35529	−0·64150 79902 22384
27·6	+0·62437 71354 16393	−0·78112 30330 55113
27·8	+0·45674 59721 44193	−0·88959 71655 36208
28·0	+0·27090 57883 07869	−0·96260 58663 13567
28·2	+0·07426 54455 84361	−0·99723 85088 79474
28·4	−0·12533 56260 96431	−0·99211 43990 64451
28·6	−0·31993 99618 84197	−0·94743 78189 56758
28·8	−0·50178 93010 20574	−0·86498 98828 20189
29·0	−0·66363 38842 12968	−0·74805 75296 89000
29·2	−0·79902 14786 59614	−0·60130 24834 81154
29·4	−0·90255 46082 10186	−0·43057 54047 76629
29·6	−0·97010 57337 07185	−0·24268 26434 42922
29·8	−0·99898 18049 46949	−0·04511 48909 44512
30·0	−0·98803 16240 92862	+0·15425 14498 87584

SINES AND COSINES (θ IN RADIANS)—*contd.*

θ	Sin θ	Cos θ
30·0	−0·98803 16240 92862	+0·15425 14498 87584
30·2	−0·93769 17403 00281	+0·34746 82721 81261
30·4	−0·84996 90458 79327	+0·52683 26309 62610
30·6	−0·72836 07678 31594	+0·68519 38352 63986
30·8	−0.57771 50444 45732	+0·81623 85236 07570
31·0	−0·40403 76453 23065	+0·91474 23578 04531
31·2	−0·21425 25402 95887	+0·97677 83008 32261
31·4	−0·01592 58626 00100	+0·99987 31754 07983
31·6	+0·18303 57289 80587	+0·98310 62617 62453
31·8	+0·37470 02636 49461	+0·92714 60038 31664
32·0	+0·55142 66812 41691	+0·83422 33605 06510
32·2	+0·70616 94571 80332	+0·70804 28643 42008
32·4	+0·83275 94853 07781	+0·55363 49335 34654
32·6	+0·92615 00206 80528	+0.37715 53250 23335
32·8	+0·98261 78773 64140	+0·18563 97238 85789
33·0	+0·99991 18601 07267	−0·01327 67472 23059
33·2	+0·97734 25123 92259	−0·21166 39163 17323
33·4	+0·91580 96028 90818	−0·40161 27130 12127
33·6	+0·81776 62545 26443	−0·57555 04782 01342
33·8	+0·68712 11462 04742	−0·72654 28620 79232
34·0	+0·52908 26861 20024	−0·84857 02747 84605
34·2	+0·34995 13689 56665	−0·93676 78684 52669
34·4	+0·15686 85950 48409	−0·98761 94833 47478
34·6	−0·04246 80347 16950	−0·99909 78260 54726
34·8	−0·24011 15979 53777	−0·97074 52912 72682
35·0	−0·42818 26694 96151	−0·90369 22050 91507
35·2	−0·59918 34492 14263	−0·80061 17624 58995
35·4	−0·74629 66756 44917	−0·66561 34553 33758
35·6	−0·86365 74086 92955	−0·50407 92402 09086
35·8	−0.94658 68462 84961	−0·32244 89764 91306
36·0	−0·99177 88534 43116	−0·12796 36896 27405
36·2	−0·99743 17674 53648	+0·07162 31057 29168
36·4	−0·96332 02244 73760	+0·26835 45138 80098
36·6	−0·89080 41440 76862	+0·45438 74744 04268
36·8	−0.78277 45135 50653	+0·62230 54402 26533
37·0	−0·64353 81333 56999	+0·76541 40519 45343
37·2	−0·47864 59185 88417	+0·87800 80208 16809
37·4	−0·29467 16015 00256	+0·95559 85806 12840
37·6	−0·09894 96575 50291	+0·99509 24405 65539
37·8	+0·10071 70969 92503	+0·99491 51051 08673
38·0	+0·29636 85787 09385	+0·95507 36440 47295
38·2	+0·48020 47804 38257	+0·87715 64107 06919
38·4	+0·64489 67329 44868	+0·76426 97192 98779
38·6	+0·78387 86877 98292	+0·62091 40059 74763
38·8	+0·89160 98730 41442	+0·45280 44106 39985
39·0	+0·96379 53862 84088	+0·26664 29323 59937
39·2	+0·99755 74189 07805	+0·06985 12418 07130
39·4	+0·99154 99852 14141	−0·12972 51973 28187
39·6	+0·94601 25826 26909	−0·32412 99022 17562
39·8	+0·86276 06436 85677	−0·50561 25707 56578
40·0	+0·74511 31604 79349	−0·66693 80616 52262

Hyperbolic Sines and Cosines, Sinh πx and Cosh πx.

The hyperbolic functions, Sinh πx and Cosh πx are required in the computation of the Elliptic θ functions with imaginary argument and the Gamma function with complex argument. To construct the following tables, values of $e^{\pm \pi x}$ were computed over the range $x=0$ to 4, first to intervals of 0·5, then 0·05, and finally to 0·01. The short table below of values of $e^{\pi x}$ to twenty places of decimals when x is a positive or negative integer or half an odd integer formed the basis of the calculations.

x	$e^{\pi x}$
4·0	286751·31313 66532 99746 69162
3·5	59609·74149 28721 55884 50138
3·0	12391·64780 79166 97481 50654
2·5	2575·97049 65975 70550 92241
2·0	535·49165 55247 64736 50305
1·5	111·31777 84898 56226 02684
1·0	23·14069 26327 79269 00573
0·5	4·81047 73809 65351 65547
−0·5	0.20787 95763 50761 90855
−1·0	0· 4321 39182 63772 24977
−1·5	0· 898 32910 21129 42789
−2·0	0· 186 74427 31707 98881
−2·5	0· 38 82032 03926 76625
−3·0	0· 8 06995 17570 30460
−3·5	0· 1 67757 81524 22579
−4·0	0· 34873 42356 20900

Tables of $e^{\frac{\pi}{360}}$ and $e^{-\frac{\pi}{360}}$ have been calculated by C. E. Van Orstrand[1] to twenty-three places of decimals from $x=0$ to $x=360$. Hayashi[2] has published these tables to ten places and given the corresponding values of Sin $\frac{\pi x}{360}$ and Cos $\frac{\pi x}{360}$ over this range. Some values of the exponential function to powers of multiples of π are given by Gauss.[3]

[1] C. E. Van Orstrand. *Fifth Memoir of the National Academy of Sciences*, vol. xiv. Washington, 1921.

[2] Hayashi. 'Tafeln der Kreis- und Hyperbel-funktionen.' Julius Springer. Berlin, 1926.

[3] Gauss. Werke. Band iii. 'De curva lemniscata.'

HYPERBOLIC SINES AND COSINES, SINH πx AND COSH πx—*contd.*

x	Sinh πx	Cosh πx
0·01	0·03142 10945 03700	1·00049 35208 08511
0·02	0·06287 32029 35328	1·00197 45703 59621
0·03	0·09438 73698 34849	1·00444 46105 10874
0·04	0·12599 47009 96518	1·00790 60792 94694
0·05	0·15772 63941 71594	1·01236 23933 24828
0·06	0·18961 37698 61821	1·01781 79511 68681
0·07	0·22168 83022 34062	1·02427 81376 88890
0·08	0·25398 16501 86615	1·03174 93293 58404
0·09	0·28652 56885 97862	1·04023 89005 54329
0·10	0·31935 25397 88101	1·04975 52308 36746
0·11	0·35249 46052 25612	1·06030 77132 19686
0·12	0·38598 45975 08257	1·07190 67634 42423
0·13	0·41985 55726 52172	1·08456 38302 50246
0·14	0·45414 09627 19433	1·09829 14066 94842
0·15	0·48887 46088 16893	1·11310 30424 65463
0·16	0·52409 07944 98761	1·12901 33572 63032
0·17	0·55982 42796 05897	1·14603 80552 30393
0·18	0·59611 03345 75223	1·16419 39404 52958
0·19	0·63298 47752 53112	1·18349 89335 45034
0·20	0·67048 39982 47118	1·20397 20893 38221
0·21	0·70864 50168 50940	1·22563 36156 89317
0·22	0·74750 54975 78090	1·24850 48934 26320
0·23	0·78710 37973 40302	1·27260 84974 52191
0·24	0·82747 90013 07404	1·29796 82190 27222
0·25	0·86867 09614 86010	1·32460 90892 52006
0·26	0·91072 03360 55100	1·35255 74037 74167
0·27	0·95366 86294 97345	1·38184 07487 43264
0·28	0·99755 82335 65752	1·41248 80280 39468
0·29	1·04243 24691 26092	1·44452 94918 02892
0·30	1·08833 56289 16394	1·47799 67662 91741
0·31	1·13531 30212 65725	1.51292 28850 98744
0·32	1·18341 10148 15392	1·54934 23217 56685
0·33	1·23267 70842 86724	1·58729 10237 65213
0·34	1·28315 98573 40596	1·62680 64480 72523
0·35	1·33490 91625 74955	1·66792 75980 46920
0·36	1·38797 60787 07720	1·71069 50619 74769
0·37	1·44241 29849 93601	1·75515 10531 22822
0·38	1·49827 36129 24603	1·80133 94514 04466
0·39	1·55561 30992 65248	1·84930 58466 91031
0·40	1·61448 80404 74852	1·89909 75838 10881
0·41	1·67495 65485 70589	1·95076 38092 80740
0·42	1·73707 83084 86469	2·00435 55198 15338
0·43	1·80091 46369 84852	2·05992 56126 63302
0·44	1·86652 85431 78643	2·11752 89378 18935
0·45	1·93398 47907 23910	2·17722 23521 61443
0·46	2·00334 99617 44310	2·23906 47755 75045
0.47	2·07469 25225 50410	2·30311 72491 05348
0·48	2·14808 28912 18793	2·36944 29952 09399
0·49	2·22359 35070 97621	2·43810 74801 58883
0·50	2·30129 89023 07295	2·50917 84786 58057
0·51	2·38127 57753 06753	2·58272 61407 40202
0·52	2·46360 30665 98045	2·65882 30610 08629
0·53	2·54836 20366 43893	2·73754 43502 90568
0·54	2·63563 63460 75147	2·81896 77097 74689
0·55	2·72551 21382 67314	2·90317 35077 05398

HYPERBOLIC SINES AND COSINES, SINH πx AND COSH πx—*contd.*

x	Sinh πx	Cosh πx
0·56	2·81807 81243 67649	2·99024 48587 09648
0·57	2·91342 56708 56754	3·08026 77058 34531
0 58	3·01164 88897 31095	3·17333 09053 76642
0·59	3·11284 47313 95459	3·26952 63145 86941
0·60	3·21711 30803 57038	3·36894 88823 37687
0·61	3·32455 68538 15595	3·47169 67428 40920
0·62	3·43528 21032 47025	3·57787 13125 11016
0·63	3·54939 81190 80570	3·68757 73900 66910
0·64	3·66701 75385 73027	3·80092 32599 72790
0·65	3·78825 64569 86406	3·91802 07993 19370
0·66	3·91323 45421 78782	4·03898 55882 51236
0·67	4·04207 51527 21458	4·16393 70240 49258
0·68	4·17490 54596 59000	4·29299 84389 80676
0·69	4·31185 65720 32358	4·42629 72220 33179
0·70	4·45306 36662 88942	4·56396 49446 53137
0·71	4·59866 61197 07401	4·70613 74906 12097
0·72	4·74880 76479 68802	4·85295 51901 29719
0·73	4·90363 64470 09980	5·00456 29583 85543
0·74	5·06330 53392 99103	5·16111 04385 56300
0·75	5·22797 19246 77804	5·32275 21495 19959
0·76	5·39779 87359 18785	5·48964 76383 72287
0·77	5·57295 33991 52426	5·66196 16379 06476
0·78	5·75360 87993 20756	5·83986 42292 11260
0·79	5·93994 32508 22079	6·02353 10095 48035
0·80	6·13214 06735 14713	6·21314 32656 72656
0·81	6·33039 06742 53539	6·40888 80527 73016
0·82	6·53488 92341 38566	6·61095 88791 99003
0·83	6·74583 79016 60317	6·81955 48971 67180
0·84	6·96344 49919 32691	7·03488 20996 28428
0·85	7·18792 52922 09947	7·25715 30234 92853
0·86	7·41950 03738 90659	7·48658 70594 12562
0·87	7·65839 88112 17912	7·72341 06683 29370
0·88	7·90485 64068 91589	7·96785 76050 01171
0·89	8·15911 64248 15451	8·22016 91487 27614
0·90	8·42142 98302 08734	8·48059 43415 02812
0·91	8·69205 55373 19264	8·74939 02338 30154
0·92	8·97126 06649 82595	9·02682 21384 41853
0·93	9·25932 08002 79417	9·31316 38921 73650
0·94	9·55652 02705 51472	9·60869 81262 53170
0·95	9·86315 24240 44476	9·91371 65452 68703
0·96	10·17951 99194 55044	10·22852 02150 93776
0·97	10·50593 50246 67418	10·55341 98600 51697
0·98	10·84271 99249 74869	10·88873 61696 13397
0·99	11·19020 70410 89984	11·23480 01149 31278
1·00	11·54873 93572 57748	11·59195 32755 21521
1·01	11·91867 07597 95266	11·96054 81764 17278
1·02	12·30036 63863 92285	12·34094 86361 25556
1·03	12·69420 29865 17293	12·73353 01257 31221
1·04	13·10056 92932 84918	13·13868 01395 02586
1·05	13·51986 64071 51697	13·55679 85773 64382
1·06	13·95250 81918 18913	13·98829 81396 15622
1·07	14·39892 16827 33294	14·43360 47342 81974
1·08	14·85954 75085 88775	14·89315 78975 04708
1·09	15·33484 03262 45348	15·36741 12273 81160
1·10	15·82526 92694 94314	15·85683 28316 84930

Hyperbolic Sines and Cosines, Sinh πx and Cosh πx—*contd.*

x	Sinh πx	Cosh πx
1·11	16·33131 84121 12851	16·36190 57899 07733
1·12	16·85348 72456 64981	16·88312 86300 78969
1·13	17·39229 11725 20532	17·42101 58208 33630
1·14	17·94826 20145 78726	17·97609 82792 14252
1·15	18·52194 85381 98526	18·54892 38947 08138
1·16	19·11391 69958 53867	19·14005 80700 37074
1·17	19·72475 16850 48422	19·75008 42792 33356
1·18	20·35505 55250 41544	20·37960 46435 52934
1·19	21·00545 06519 54677	21·02924 05257 94154
1·20	21·67657 90328 45592	21·69963 31436 08699
1·21	22·36910 30993 56593	22·39144 42024 10097
1·22	23·08370 64015 62116	23·10535 65485 04500
1·23	23·82109 42826 61098	23·84207 48430 88410
1·24	24·58199 45751 80072	24·60232 62577 78603
1·25	25·36715 83193 74159	25·38686 11923 60776
1·26	26·17736 05045 35055	26·19645 40154 65372
1·27	27·01340 08339 37717	27·03190 38289 01636
1·28	27·87610 45141 80772	27·89403 52564 04363
1·29	28·76632 30696 99780	28·78369 92575 71842
1·30	29·68493 51832 57283	29·70177 39677 98390
1·31	30·63284 75632 39262	30·64916 55650 30536
1·32	31·61099 58386 14051	31·62680 91642 02367
1·33	32·62034 54824 37062	32·63566 97402 32879
1·34	33·66189 27648 12875	33·67674 30804 96388
1·35	34·73666 57362 55291	34·75105 67677 06106
1·36	35·84572 52424 15975	35·85967 11941 81045
1·37	36·99016 59711 83261	37·00368 06084 97367
1·38	38·17111 75331 84657	38·18421 41955 57267
1·39	39·38974 55767 59546	39·40243 71911 41466
1·40	40·64725 29385 02606	40·65955 20320 45419
1·41	41·94488 08305 13590	41·95679 95429 34473
1·42	43·28391 00655 25320	43·29546 01610 89455
1·43	44·66566 23211 19163	44·67685 52002 51551
1·44	46·09150 14442 75803	46·10234 81548 13964
1·45	47·56283 47975 48976	47·57334 60456 47616
1·46	49·08111 46481 90872	49·09130 08088 89314
1·47	50·64783 96016 00364	50·65771 07290 63133
1·48	52·26455 60805 08891	52·27412 19179 49601
1·49	53·93285 98513 64063	53·94212 98406 62369
1·50	55·65439 75994 17548	55·66338 08904 38678
1·51	57·43086 85540 71950	57·43957 40136 97998
1·52	59·26402 61660 90943	59·27246 23869 72856
1·53	61·15567 98383 28150	61·16385 51473 67029
1·54	63·10769 67116 83063	63·11561 91782 49161
1·55	65·12200 35080 46812	65·12968 09519 44340
1·56	67·20058 84320 56859	67·20802 84312 42454
1·57	69·34550 31335 37715	69·35271 30316 00206
1·58	71·55886 47325 64704	71·56585 16459 73533
1·59	73·84285 79091 49586	73·84962 87342 79061
1·60	76·19973 70596 10643	76·20629 84795 46949
1·61	78·63182 85217 55672	78·63818 70128 93353
1·62	81·14153 28710 74215	81·14769 47095 08645
1·63	83·73132 72902 05469	83·73729 85579 27621
1·64	86·40376 80140 20649	86·40955 46049 20270
1·65	89·16149 28527 33185	89·16710 04784 16314

HYPERBOLIC SINES AND COSINES, SINH πx AND COSH πx—*contd.*

x	Sinh πx	Cosh πx
1·66	92·00722 37955 27182	92·01265 79909 53741
1·67	94·94376 96972 74024	94·94903 58262 21054
1·68	97·97402 90509 89031	97·97913 23113 44964
1·69	101·10099 28487 64691	101·10593 82776 59879
1·70	104·32774 75340 04329	104·33254 00127 82907
1·71	107·65747 80478 70197	107·66212 23069 08168
1·72	111·09347 09729 52949	111·09797 15963 27264
1·73	114·63911 77772 65436	114·64347 92072 78667
1·74	118·29791 81617 62774	118·30214 47033 27855
1·75	122·07348 35146 92839	122·07757 93395 82190
1·76	125·96954 04761 86760	125·97350 96271 50003
1·77	129·98993 46166 07819	129·99378 10113 62138
1·78	134·13863 42322 89443	134·14236 16673 86538
1·79	138·41973 42624 08834	138·42334 64169 82269
1·80	142·83746 03308 62353	142·84096 07702 59020
1·81	147·39617 29171 32168	147·39956 50964 31429
1·82	152·10037 16602 60969	152·10365 89276 84965
1·83	156·95469 98001 82966	156·95788 54004 01451
1·84	161·96394 87607 94945	161·96703 58381 27909
1·85	167·13306 28792 91053	167·13605 44808 12298
1·86	172·46714 42864 29382	172·47004 33649 74112
1·87	177·97145 79425 47361	177·97426 73596 26751
1·88	183·65143 68342 96721	183·65415 93629 22349
1·89	189·51268 73372 27427	189·51532 56646 48348
1·90	195·56099 47495 13661	195·56355 14798 68839
1·91	201·80232 90022 83892	201·80480 66591 72592
1·92	208·24285 05521 91352	208·24525 15811 64035
1·93	214·88891 64620 41124	214·89124 32330 13311
1·94	221·74708 66754 75703	221·74934 14850 67175
1·95	228·82413 04919 12370	228·82631 55657 14033
1·96	236·12703 32481 23435	236·12915 07428 94068
1·97	243·66300 32130 54344	243·66505 52188 49409
1·98	251·43947 87026 85112	251·44146 72449 19727
1·99	259·46413 54219 57756	259·46606 24634 05864
2·00	267·74489 40410 16514	267·74676 14837 48222
2·01	276·28992 80132 38911	276·29173 77004 97913
2·02	285·10767 16427 74398	285·10942 53607 97331
2·03	294·20682 84095 53556	294·20852 78893 33095
2·04	303·59637 95599 85005	303·59802 64789 78419
2·05	313·28559 29718 19378	313·28718 89556 04253
2·06	323·28403 23019 30363	323·28557 89258 09115
2·07	333·60156 64260 42050	333·60306 52165 96813
2·08	344·24837 91797 19982	344·24983 16163 19408
2·09	355·23497 94102 40679	355·23638 69265 00140
2·10	366·57221 13492 61251	366·57357 53344 57870
2·11	378·27126 53165 27341	378·27258 71169 71273
2·12	390·34368 87651 84429	390·34496 96855 47720
2·13	402·80139 76795 94651	402·80263 89841 99008
2·14	415·65668 83369 09276	415·65789 12509 74004
2·15	428·92224 94440 05989	428·92341 51548 57331
2·16	442·61117 46617 70643	442·61230 43200 13723
2·17	456·73697 55290 85474	456·73807 02497 39991
2·18	471·31359 47992 80289	471·31465 56628 81088
2·19	486·35542 02022 10254	486·35644 82558 73858
2·20	501·87729 86455 44041	501·87829 49040 02201

Hyperbolic Sines and Cosines, Sinh πx and Cosh πx—*contd.*

x	Sinh πx			Cosh πx		
2·21	517·89455	08692	79577	517·89551	63158	80853
2·22	534·42298	65679	52028	534·42392	21556	32395
2·23	551·47891	99954	60257	551·47982	66476	83691
2·24	569·07918	60679	14372	569·08006	46795	84350
2·25	587·24115	69803	98545	587·24200	84187	41351
2·26	605·98275	93540	50543	605·98358	44594	71254
2·27	625·32249	19303	82839	625·32329	15172	94845
2·28	645·27944	38303	10349	645·28021	86879	39208
2·29	665·87331	33959	07209	665·87406	42890	69649
2·30	687·12442	76334	90187	687·12515	53033	49008
2·31	709·05376	22772	19867	709·05446	74420	15503
2·32	731·68296	24930	23213	731·68364	58487	82665
2·33	755·03436	42432	73147	755·03502	64644	96988
2·34	779·13101	63333	12966	779·13165	80736	41105
2·35	803·99670	31615	86442	803·99732	50544	43289
2·36	829·65596	81958	28916	829·65657	08550	48602
2·37	856·13413	81984	91385	856·13472	22189	23642
2·38	883·45734	82253	09061	883·45791	41834	06359
2·39	911·65256	74216	89047	911·65311	58760	75582
2·40	940·74762	56423	79228	940·74815	71344	02305
2·41	970·77124	09206	93104	970·77175	59749	57470
2·42	1001·75304	78144	03831	1001·75354	69392	89478
2·43	1033·72362	66562	86041	1033·72411	03444	50004
2·44	1066·71453	37381	76956	1066·71500	24670	39582
2·45	1100·75833	24583	49708	1100·75878	66905	65893
2·46	1135·88862	54629	42632	1135·88906	56468	58476
2·47	1172·14008	78131	69436	1172·14051	43832	64784
2·48	1209·54850	12110	47704	1209·54891	45883	64991
2·49	1248·15078	93174	27905	1248·15118	99099	87748
2·50	1287·98505	41971	83312	1287·98544	24003	87239
2·51	1329·09061	39275	33722	1329·09099	01245	54451
2·52	1371·50804	14066	23977	1371·50840	59687	83624
2·53	1415·27920	44006	62953	1415·27955	76877	98540
2·54	1460·44730	68691	51221	1460·44764	92299	73856
2·55	1507·05693	16089	87094	1507·05726	33814	20157
2·56	1555·15408	42595	42572	1555·15440	57710	59261
2·57	1604·78623	87121	44013	1604·78655	02800	89575
2·58	1656·00238	39687	78601	1656·00268	59006	83566
2·59	1708·85307	24962	78080	1708·85336	50901	61803
2·60	1763·39047	01237	07361	1763·39075	36683	72183
2·61	1819·66840	75322	08797	1819·66868	23075	25101
2·62	1877·74243	33881	24738	1877·74269	96653	07198
2·63	1937·66986	91718	42988	1937·67012	72137	18264
2·64	1999·50986	57564	83492	1999·51011	58177	49654
2·65	2063·32346	17922	71792	2063·32370	41197	49716
2·66	2129·17364	39542	27042	2129·17387	87871	04035
2·67	2197·12540	91126	31575	2197·12563	66826	97459
2·68	2267·24582	84876	46844	2267·24604	90195	22744
2·69	2339·60411	38513	99028	2339·60432	75627	59084
2·70	2414·27168	58428	78506	2414·27189	29446	64724
2·71	2491·32224	44630	82857	2491·32244	51597	13320
2·72	2570·83184	18199	85020	2570·83203	63095	55654
2·73	2652·87895	71951	28923	2652·87914	56696	09027
2·74	2737·54457	45059	46439	2737·54475	71513	68171
2·75	2824·91226	22402	54209	2824·91243	92368	96201

HYPERBOLIC SINES AND COSINES, SINH πx AND COSH πx—*contd.*

x	Sinh πx			Cosh πx		
2·76	2915·06825	59418	28980	2915·06842	74643	94282
2·77	3008·10154	33284	78182	3008·10170	95462	66705
2·78	3104·10395	21266	20810	3104·10411	32036	96429
2·79	3203·17024	07090	74992	3203·17039	68044	27485
2·80	3305·39819	16255	15527	3305·39834	28932	17502
2·81	3410·88870	81179	19827	3410·88885	47072	78801
2·82	3519·74591	37162	67045	3519·74605	57719	72816
2·83	3632·07725	50127	95473	3632·07739	26750	62936
2·84	3747·99360	77162	60692	3747·99374	11209	68232
2·85	3867·60938	60908	74426	3867·60951	53696	98043
2·86	3991·04265	58879	44904	3991·04278	11684	88176
2·87	4118·41525	08816	86943	4118·41537	22876	06980
2·88	4249·85289	31242	27460	4249·85301	07753	56958
2·89	4385·48531	70385	03096	4385·48543	10509	68616
2·90	4525·44639	74715	34815	4525·44650	79578	71406
2·91	4669·87428	18344	73390	4669·87438	89037	35664
2·92	4818·91152	64598	43486	4818·91163	02177	13260
2·93	4972·70523	73105	76637	4972·70533	78594	67248
2·94	5131·40721	51797	18771	5131·40731	26188	76157
2·95	5295·17410	55241	30442	5295·17419	99497	31107
2·96	5464·16755	30800	71868	5464·16764	45853	17810
2·97	5638·55436	14132	84793	5638·55445	00884	95498
2·98	5818·50665	75610	53746	5818·50674	34937	55337
2·99	6004·20206	19287	55248	6004·20214	52037	66877
3·00	6195·82386	36085	89956	6195·82394	43081	07526
3·01	6393·56120	12935	44610	6393·56127	94972	21903
3·02	6597·60924	99651	53400	6597·60932	57501	80701
3·03	6808·16941	35393	27343	6808·16948	69805	07627
3·04	7025·44952	36604	01115	7025·44959	48302	23884
3·05	7249·66404	48396	15348	7249·66411	38083	28178
3·06	7481·03428	61405	14595	7481·03435	29761	92476
3·07	7719·78861	96202	03274	7719·78868	43888	15802
3·08	7966·16270	57420	70196	7966·16276	85075	46687
3·09	8220·39972	59824	73415	8220·39978	68067	66006
3·10	8482·75062	28609	77883	8482·75068	18041	22683
3·11	8753·47434	76310	65740	8753·47440	47512	42085
3·12	9032·83811	58758	00283	9032·83817	12293	88165
3·13	9321·11767	12607	27164	9321·11772	49023	62877
3·14	9618·59755	77043	47915	9618·59760	96869	77987
3·15	9925·57140	02348	09380	9925·57145	06097	42829
3·16	10242·34219	48100	26293	10242·34224	36269	85276
3·17	10569·22260	73873	01532	10569·22265	46944	70418
3·18	10906·53528	25376	38201	10906·53532	83817	11135
3·19	11254·61316	19093	58717	11254·61320	63355	85707
3·20	11613·79981	28553	67746	11613·79985	59075	99326
3·21	11984·44976	75484	27765	11984·44980	92691	58280
3·22	12366·92887	29191	68157	12366·92891	33495	77705
3·23	12761·61465	17622	31200	12761·61469	09422	26277
3·24	13168·89667	53669	81752	13168·89671	33352	34644
3·25	13589·17694	80405	82655	13589·17698	48345	69608
3·26	14022·87030	39029	76121	14022·87033	95590	14331
3·27	14470·40481	63454	24282	14470·40485	08987	07742
3·28	14932·22222	05567	61500	14932·22225	40413	95739
3·29	15408·77834	95344	09452	15408·77838	19834	45199
3·30	15900·54358	40105	16000	15900·54361	54559	81802

HYPERBOLIC SINES AND COSINES, SINH πx AND COSH πx—*contd.*

x	Sinh πx			Cosh πx		
3·31	16408·00331	67373	13659	16408·00334	72102	47501
3·32	16931·65843	15899	66660	16931·65846	11204	46594
3·33	17472·02579	79598	01025	17472·02582	65769	74865
3·34	18029·63878	09259	04375	18029·63880	86580	18462
3·35	18605·04776	77086	56054	18605·04779	45830	83139
3·36	19198·82071	09248	19121	19198·82073	69680	85381
3·37	19811·54368	91804	09591	19811·54371	44182	20815
3·38	20443·82148	55546	71422	20443·82151	00119	38379
3·39	21096·27818	45461	44994	21096·27820	82470	08025
3·40	21769·55778	80700	39711	21769·55781	10378	92555
3·41	22464·32485	11149	25756	22464·32487	33724	38638
3·42	23181·26513	76861	64603	23181·26515	92553	06615
3·43	23921·08629	76835	21770	23921·08631	85855	82553
3·44	24684·51856	53810	68169	24684·51858	56366	78926
3·45	25472·31548	01987	98784	25472·31549	98279	52647
3·46	26285·25463	04774	00283	26285·25464	94994	72043
3·47	27124·13842	09903	04174	27124·13843	94240	69408
3·48	27989·79486	49505	91892	27989·79488	28142	45493
3·49	28883·07840	12944	95544	28883·07841	86056	69682
3·50	29804·87073	80481	87180	29804·87075	48239	68704
3·51	30756·08172	26102	94687	30756·08173	88672	41991
3·52	31737·65023	98091	49370	31737·65025	55633	08739
3·53	32750·54513	86211	85109	32750·54515	38881	06553
3·54	33795·76618	84651	98710	33795·76620	32599	51316
3·55	34874·34506	60163	73678	34874·34508	03535	60482
3·56	35987·34637	35140	93938	35987·34638	74078	66341
3·57	37135·86868	95686	59681	37135·86870	30327	31414
3·58	38321·04565	35040	95301	38321·04566	65517	55964
3·59	39544·04708	43073	40898	39544·04709	69514	69074
3·60	40806·08013	52882	76773	40806·08014	75413	52743
3·61	42108·39048	55902	78403	42108·39049	74643	96462
3·62	43452·26356	97273	72410	43452·26358	12342	52808
3·63	44839·02584	63615	97864	44839·02585	75125	98371
3·64	46270·04610	75729	08972	46270·04611	83790	36089
3·65	47746·73682	99139	23044	47746·73684	03858	42868
3·66	49270·55556	85830	60994	49270·55557	87311	09746
3·67	50843·00639	60921	87288	50843·00640	59263	81515
3·68	52465·64138	68487	74175	52465·64139	63788	20635
3·69	54140·06214	91179	34573	54140·06215	83532	39818
3·70	55867·92140	58764	33906	55867·92141	48261	13568
3·71	57650·92462	61190	49578	57650·92463	47919	37363
3·72	59490·83170	82274	45359	59490·83171	66321	01768
3·73	61389·45871	70631	15818	61389·45872	52078	36596
3·74	63348·67967	64989	83827	63348·67968	43918	08153
3·75	65370·42841	91589	54433	65370·42842	68076	72853
3·76	67456·70049	51911	95001	67456·70050	26033	57119
3·77	69609·55514	19591	80318	69609·55514	91421	02245
3·78	71831·11731	65946	69660	71831·11732	35554	41240
3·79	74123·57979	34188	30235	74123·57980	01643	22039
3·80	76489·20532	83017	48904	76489·20533	48386	19013
3·81	78930·32889	20966	45124	78930·32889	84313	45701
3·82	81449·35997	53532	77608	81449·35998	14920	61266
3·83	84048·78496	65854	92754	84048·78497	25342	18728
3·84	86731·16960	64396	63804	86731·16961	22046	03931
3·85	89499·16152	01884	87590	89499·16152	57751	32107
3·86	92355·49283	10463	14675	92355·49283	64601	77832

HYPERBOLIC SINES AND COSINES, SINH πx AND COSH πx—*contd.*

x	Sinh πx			Cosh πx		
3·87	95302·98285	68889	64842	95302·98286	21353	90347
3·88	98344·54089	30377	02145	98344·54089	81218	68439
3·89	101483·16908	38547	93205	101483·16908	87817	18571
3·90	104721·96538	59849	33073	104721·96539	07594	80592
3·91	108064·12662	61673	81276	108064·12663	07942	63624
3·92	111512·95165	66369	95873	111512·95166	11207	79976
3·93	115071·84461	12286	77668	115071·84461	55737	89208
3·94	118744·31826	53991	35168	118744·31826	96098	62951
3·95	122533·99750	34824	51611	122533·99750	75629	51801
3·96	126444·62289	66017	79594	126444·62290	05560	79813
3·97	130480·05439	47687	11056	130480·05439	86007	14364
3·98	134644·27513	68145	78346	134644·27514	05280	67089
3·99	138941·39538	19142	47123	138941·39538	55128	86669
4·00	143375·65656	65829	78695	143375·65657	00703	21051

SINE AND COSINE INTEGRALS. Si (x) AND Ci (x).

These integrals were tabulated to ten places of decimals over the range $x=5{\cdot}0$ to $x=20{\cdot}0$ by 0·1 intervals and published in last year's Report. Values of these functions for the range $x=20{\cdot}0$ to 40·0 by 0·2 intervals were required in the construction of tables of Bessel function derivatives $\frac{\delta}{\delta\nu}\cdot J\nu\,(x)$ when ν is half an odd integer. For large values of x, the asymptotic series were used in the manner set out in the prefatory note to the tables published last year. Twenty values were computed in this way for integer values of x from 20 to 40. The differential coefficients of these functions $\frac{\sin x}{x}$ and $\frac{\cos x}{x}$ were next computed for smaller intervals and differenced, and the first difference of Si (x) and Ci (x) obtained from the central difference interpolation formula

$$\Delta_1=\mu f_{\frac{1}{2}}-\frac{1}{12}\mu\delta^2 f_{\frac{1}{2}}+\frac{11}{720}\mu\delta^4 f_{\frac{1}{2}}-\frac{191}{60480}\mu\delta^6 f_{\frac{1}{2}}+\ \ldots$$

where f represents either $\frac{\sin x}{x}$ or $\frac{\cos x}{x}$.

The comparison of the difference of two entries of Si (x) or Ci (x) for integer values of x and the sum of the first differences as calculated above served as a check on the work. An error in the tables of Si (x) published last year has been discovered and is here corrected

$$\text{Si}\,(5{\cdot}3) = +1{\cdot}49731\ 50636$$

A short table of Si (x) to five decimal places for integer values of x from 16 to 60 appeared in 1914 in a paper by Lord Rayleigh.[1] Bretschneider also has tabulated[2] the sine and cosine integrals for $x=0{\cdot}0$ to 1·0 by 0·01 intervals and $x=1{\cdot}0$ to 7·5 by 0·1 intervals to ten places.

[1] Lord Rayleigh. *Proc. Roy. Soc.*, vol. xc, p. 320. (1914.)
[2] Bretschneider. *Zeit. für Math. u. Phys.*, Band vi, 127–139. (1861.)

Sine and Cosine Integrals. Si (x) and Ci (x)—*contd.*

x	Si (x)	Ci (x)
20·0	+1·54824 17010	+0·04441 98208
20·2	+1·55766 95529	+0·04754 95340
20·4	+1·56743 40941	+0·04873 20536
20·6	+1·57714 32653	+0·04795 86903
20·8	+1·58641 47963	+0·04529 77742
21·0	+1·59489 09681	+0·04089 05002
21·2	+1·60225 21386	+0·03494 40166
21·4	+1·60822 85319	+0·02772 20745
21·6	+1·61260 98649	+0·01953 36456
21·8	+1·61525 24777	+0·01071 99886
22·0	+1·61608 37366	+0·00164 06919
22·2	+1·61510 35866	−0·00734 07442
22·4	+1·61238 32456	−0·01587 12202
22·6	+1·60806 11397	−0·02362 16886
22·8	+1·60233 62873	−0·03029 96260
23·0	+1·59545 94323	−0·03565 98604
23·2	+1·58772 23115	−0·03951 33615
23·4	+1·57944 55042	−0·04173 36863
23·6	+1·57096 53627	−0·04226 08691
23·8	+1·56262 05464	−0·04110 26465
24·0	+1·55473 86917	−0·03833 30156
24·2	+1·54762 37352	−0·03408 82234
24·4	+1·54154 43721	−0·02856 03885
24·6	+1·53672 40839	−0·02198 90396
24·8	+1·53333 30960	−0·01465 09366
25·0	+1·53148 25510	−0·00684 85972
25·2	+1·53122 10879	+0·00110 20008
25·4	+1·53253 39239	+0·00888 40504
25·6	+1·53534 44351	+0·01619 23800
25·8	+1·53951 81356	+0·02274 52672
26·0	+1·54486 88630	+0·02829 51510
26·2	+1·55116 68942	+0·03263 78404
26·4	+1·55814 86456	+0·03561 98815
26·6	+1·56552 75545	+0·03714 38243
26·8	+1·57300 56979	+0·03717 12130
27·0	+1·58028 56840	+0·03572 32167
27·2	+1·58708 23469	+0·03287 89161
27·4	+1·59313 37895	+0·02877 13327
27·6	+1·59821 13521	+0·02358 14087
27·8	+1·60212 81314	+0·01753 01874
28·0	+1·60474 57383	+0·01086 95343
28·2	+1·60597 90526	+0·00387 17741
28·4	+1·60579 88192	−0·00318 13179
28·6	+1·60423 20126	−0·01000 97517
28·8	+1·60135 99870	−0·01634 63251
29·0	+1·59731 45151	−0·02194 69730
29·2	+1·59227 18998	−0·02660 00640
29·4	+1·58644 54167	−0·03013 42950
29·6	+1·58007 64051	−0·03242 48925
29·8	+1·57342 43763	−0·03339 79016
30·0	+1·56675 65400	−0·03303 24173

Sine and Cosine Integrals, Si (x) and Ci (x)—*contd.*

x	Si (x)	Ci (x)
30·0	+1·56675 65400	−0·03303 24173
30·2	+1·56033 71676	−0·03136 07011
30·4	+1·55441 72116	−0·02846 62038
30·6	+1·54922 45863	−0·02447 96007
30·8	+1·54495 54815	−0·01957 30204
31·0	+1·54176 70373	−0·01395 27171
31·2	+1·53977 16511	−0·00785 04951
31·4	+1·53903 31179	−0·00151 42366
31·6	+1·53956 47338	+0·00480 20820
31·8	+1·54132 94113	+0·01084 84876
32·0	+1·54424 17771	+0·01638 88234
32·2	+1·54817 21454	+0·02120 98946
32·4	+1·55295 21872	+0·02512 95967
32·6	+1·55838 20512	+0·02800 37180
32·8	+1·56423 86395	+0·02973 11666
33·0	+1·57028 46982	+0·03025 74342
33·2	+1·57627 83551	+0·02957 61827
33·4	+1·58198 27254	+0·02772 89134
33·6	+1·58717 52043	+0·02480 27546
33·8	+1·59165 60874	+0·02092 64772
34·0	+1·59525 61852	+0·01626 49164
34·2	+1·59784 31461	+0·01101 20366
34·4	+1·59932 62521	+0·00538 29294
34·6	+1·59965 95173	−0·00039 49279
34·8	+1·59884 29866	−0·00609 08021
35·0	+1·59692 22045	−0·01147 98564
35·2	+1·59398 58948	−0·01635 19657
35·4	+1·59016 19637	−0·02051 98517
35·6	+1·58561 20028	−0·02382 62241
35·8	+1·58052 45241	−0·02614 96590
36·0	+1·57510 72096	−0·02740 89958
36·2	+1·56957 84898	−0·02756 60975
36·4	+1·56415 87917	−0·02662 68812
36·6	+1·55906 18040	−0·02464 06001
36·8	+1·55448 61037	−0·02169 74220
37·0	+1·55060 74710	−0·01792 44197
37·2	+1·54757 21862	−0·01348 01477
37·4	+1·54549 15643	−0·00854 80346
37·6	+1·54443 79280	−0·00332 88641
37·8	+1·54444 21632	+0·00196 73491
38·0	+1·54549 29372	+0·00712 97618
38·2	+1·54753 75912	+0·01195 50491
38·4	+1·55048 46566	+0·01625 53665
38·6	+1·55420 78773	+0·01986 56181
38·8	+1·55855 15642	+0·02264 97503
39·0	+1·56333 70577	+0·02450 58334
39·2	+1·56837 00306	+0·02536 97438
39·4	+1·57344 83354	+0·02521 73135
39·6	+1·57837 00813	+0·02406 48810
39·8	+1·58294 16190	+0·02196 82345
40·0	+1·58698 51194	+0·01902 00079

BESSEL FUNCTION DERIVATIVE, $\frac{\delta}{\delta\nu} \cdot J\nu(x)$.

Some twenty years ago Schafheitlin [1] discovered that the Sine and Cosine integrals Si (x) and Ci (x) were closely related to Bessel functions and could be expressed in terms of the derivatives with respect to the order ν of the functions, ν having the values $\pm\frac{1}{2}$. This relation followed from the consideration of the integrals

$$\int_x^\infty \sin u \sin (u-x)\frac{du}{u^2} = \sqrt{\frac{\pi x}{2}}\left[-\frac{\pi}{2}\cdot J_{-\frac{1}{2}}(x) + V_{\frac{1}{2}}(x)\right]$$

$$\text{and} \int_x^\infty \cos u \sin (u-x)\frac{du}{u^2} = \sqrt{\frac{\pi x}{2}}\left[-\frac{\pi}{2}\cdot J_{\frac{1}{2}}(x) + W_{\frac{1}{2}}(x)\right]$$

By partial integration of these two integrals

$$\text{si}\,(2x) = -\frac{\pi}{2}\cos 2x - \sqrt{\frac{\pi x}{2}}\left[\cos x \cdot V_{\frac{1}{2}}(x) - \sin x \cdot W_{\frac{1}{2}}(x)\right]$$

$$\text{and} \quad \text{ci}\,(2x) = +\frac{\pi}{2}\sin 2x + \sqrt{\frac{\pi x}{2}}\left[\sin x \cdot V_{\frac{1}{2}}(x) - \cos x \cdot W_{\frac{1}{2}}(x)\right]$$

$$\text{where si}\,(x) = \text{Si}\,(x) - \frac{\pi}{2} \text{ and ci}\,(x) = \text{Ci}\,(x).$$

$$V_{\frac{1}{2}}(x) = \left[\frac{\delta}{\delta\nu}\cdot J_\nu(x)\right]_{\nu=\frac{1}{2}} \text{ and } W_{\frac{1}{2}}(x) = -\left[\frac{\delta}{\delta\nu}\cdot J_\nu(x)\right]_{\nu=-\frac{1}{2}}$$

Eliminating $V_{\frac{1}{2}}(x)$ and $W_{\frac{1}{2}}(x)$ in turn, each of these derivatives is expressed in terms of the sine and cosine integrals

$$\left[\frac{\delta}{\delta\nu}\cdot J_\nu(x)\right]_{\nu=\frac{1}{2}} = J_{\frac{1}{2}}(x)\,\text{Ci}\,(2x) - J_{-\frac{1}{2}}(x)\,\text{Si}\,(2x)$$

$$\text{and} \left[\frac{\delta}{\delta\nu}\cdot J_\nu(x)\right]_{\nu=-\frac{1}{2}} = J_{-\frac{1}{2}}(x)\,\text{Ci}\,(2x) + J_{\frac{1}{2}}(x)\,\text{Si}\,(2x)$$

a result independently discovered by P. R. Ansell and R. A. Fisher.[2]

Tables of $J_{\frac{1}{2}}(x)$ and $J_{-\frac{1}{2}}(x)$ to six places of decimals were published in the Report for 1925.

From the relation between Bessel functions of different orders,

$$J_{\nu-1}(x) + J_{\nu+1}(x) = \frac{2\nu}{x}\cdot J_\nu(x)$$

by differentiating with respect to ν, the recurrence formula may be obtained for the calculation of derivatives of higher or lower orders.

$$\frac{\delta}{\delta\nu}\cdot J_{\nu-1}(x) + \frac{\delta}{\delta\nu}\cdot J_{\nu+1}(x) = \frac{2\nu}{x}\cdot\frac{\delta}{\delta\nu}J_\nu(x) + \frac{2}{x}J_\nu(x)$$

and in particular

$$\frac{\delta}{\delta\nu}\cdot J_{\frac{3}{2}}(x) = \frac{1}{x}\left[2J_{\frac{1}{2}}(x) + \frac{\delta}{\delta\nu}\cdot J_{\frac{1}{2}}(x)\right] - \frac{\delta}{\delta\nu}\cdot J_{-\frac{1}{2}}(x)$$

$$\text{and} \ \frac{\delta}{\delta\nu}\cdot J_{-\frac{3}{2}}(x) = \frac{1}{x}\left[2J_{-\frac{1}{2}}(x) - \frac{\delta}{\delta\nu}\cdot J_{-\frac{1}{2}}(x)\right] - \frac{\delta}{\delta\nu}\cdot J_{\frac{1}{2}}(x).$$

For integral values of the parameter ν,

$$\left[\frac{\delta}{\delta\nu}\ J_\nu(x)\right]_{\nu=n} = -G_n(x) + \frac{n!}{2}\sum_{p=0}^{n-1}\left(\frac{2}{x}\right)^{n-p}\cdot\frac{Jp(x)}{(n-p)\cdot p!}$$

$$\text{and} \left[\frac{\delta}{\delta\nu}\cdot J_\nu(x)\right]_{\nu=-n} = (-1)^{n+1}\left[G_n(x) + \frac{n!}{2}\sum_{p=0}^{n-1}\left(\frac{2}{x}\right)^{n-p}\cdot\frac{Jp(x)}{(n-p)\cdot p!}\right]$$

Tables of $G_n(x)$, Bessel functions of the second kind have been published for various values of n and x in the Reports for 1913 and 1914.

Dr. Fisher[3] has drawn attention to the importance of these derivatives in a recently published paper on the 'Theory of Statistical Estimations.'

[1] Schafheitlin. 'Beziehungen zwischen dem Integrallogarithmus und den Besselschen funktionen.' *Sitzungsber Berliner Math. Gesell.* viii. Jahrgang, 1909.

[2] P. R. Ansell and R. A. Fisher. 'Note on the numerical evaluation of a Bessel function derivative.' *Proc. Lond. Math. Soc.*, vol. xxiv. (1926).

[3] R. A. Fisher. *Proc. Camb. Phil. Soc.* 22. (1925).

Bessel Function Derivative, $\frac{\delta J\nu(x)}{\delta\nu}$.

x	$\nu=\frac{3}{2}$	$\nu=\frac{1}{2}$	$\nu=-\frac{1}{2}$	$\nu=-\frac{3}{2}$
0·0	0·000000	0·000000	$-\infty$	$+\infty$
0·1	−0·031075	−0·763515	−2·566219	+76·636251:
0·2	−0·071179	−0·827506	−0·521845	+20·922335
0·3	−0·112461	−0·828067:	+0·222192	+ 9·365217
0·4	−0·152697:	−0·799749:	+0·609708:	+ 5·085375:
0·5	−0·190680:	−0·754328	+0·845919	+ 3·023473:
0·6	−0·225617	−0·697458:	+1·001913:	+ 1·861432:
0·7	−0·256940:	−0·632447	+1·108762	+ 1·132487
0·8	−0·284229	−0·561509:	+1·182157:	+ 0·637577
0·9	−0·307167	−0·486290:	+1·230872:	+ 0·280435
1·0	−0·325526	−0·408104	+1·260215:	+ 0·010086
1·1	−0·339149	−0·328060	+1·273619:	− 0·202367
1·2	−0·347946:	−0·247133:	+1·273444	− 0·374188:
1·3	−0·351887:	−0·166199:	+1·261410	− 0·516126
1·4	−0·350997:	−0·086059:	+1·238846	− 0·635095
1·5	−0·345355	−0·007452	+1·206837:	− 0·735662:
1·6	−0·335086	+0·068940:	+1·166316:	− 0·820912
1·7	−0·320364:	+0·142486:	+1·118119:	− 0·892963:
1·8	−0·301405	+0·212603:	+1·063024	− 0·953304:
1·9	−0·278464:	+0·278760:	+1·001772	− 1·002993
2·0	−0·251833:	+0·340475	+0·935087	− 1·042804:
2·1	−0·221837	+0·397317:	+0·863680	− 1·073322
2·2	−0·188828:	+0·448909:	+0·788258	− 1·095003:
2·3	−0·153187	+0·494927	+0·709523	− 1·108227:
2·4	−0·115312:	+0·535100	+0·628175:	− 1·113324:
2·5	−0·075622:	+0·569213:	+0·544911:	− 1·110601
2·6	−0·034547	+0·597109:	+0·460423	− 1·100358:
2·7	+0·007475	+0·618686	+0·375390:	− 1·082902
2·8	+0·050000	+0·633895	+0·290485	− 1·058552
2·9	+0·092583:	+0·642746:	+0·206361	− 1·027648
3·0	+0·134786	+0·645303	+0·123653:	− 0·990553
3·1	+0·176175:	+0·641680:	+0·042975	− 0·947657
3·2	+0·216331:	+0·632047	−0·035090	− 0·899375:
3·3	+0·254851	+0·616618:	−0·109988	− 0·846150:
3·4	+0·291349	+0·595658	−0·181200	− 0·788450:
3·5	+0·325463:	+0·569472:	−0·248245:	− 0·726766:
3·6	+0·356860	+0·538409:	−0·310685	− 0·661612
3·7	+0·385231:	+0·502852	−0·368123:	− 0·593517
3·8	+0·410304:	+0·463218	−0·420214	− 0·523029
3·9	+0·431838	+0·419953:	−0·466657	− 0·450705
4·0	+0·449628	+0·373529	−0·507206	− 0·377111
4·1	+0·463508	+0·324436:	−0·541665	− 0·302815
4·2	+0·473351:	+0·273183	−0·569893	− 0·228386

Bessel Function Derivative, $\frac{\delta J\nu(x)}{\delta\nu}$ (*contd.*)

x	$\nu=\frac{3}{2}$	$\nu=\frac{1}{2}$	$\nu=-\frac{1}{2}$	$\nu=-\frac{3}{2}$
4·3	+0·479069:	+0·220286:	−0·591801:	−0·154387
4·4	+0·480616:	+0·166271:	−0·607358	−0·081373
4·5	+0·477985	+0·111664	−0·616581:	−0·009884:
4·6	+0·471209	+0·056988	−0·619546:	+0·059555:
4·7	+0·460362:	+0·002759	−0·616375	+0·126444:
4·8	+0·445557:	−0·050520	−0·607243:	+0·190306:
4·9	+0·426944	−0·102362	−0·592374	+0·250694:
5·0	+0·404707	−0·152300:	−0·572034:	+0·307194:
5·1	+0·379066	−0·199893:	−0·546535	+0·359427
5·2	+0·350271	−0·244727:	−0·516225	+0·407052:
5·3	+0·318601:	−0·286421:	−0·481491	+0·449772:
5·4	+0·284362:	−0·324627:	−0·442750	+0·487331
5·5	+0·247882	−0·359036	−0·400448	+0·519518:
5·6	+0·209507:	−0·389377	−0·355054:	+0·546171
5·7	+0·169603	−0·415423:	−0·307059	+0·567173:
5·8	+0·128544:	−0·436989:	−0·256965	+0·582457:
5·9	+0·086717:	−0·453935	−0·205287	+0·592004:
6·0	+0·044512	−0·466165	−0·152545	+0·595843:
6·1	+0·002320:	−0·473632	−0·099259:	+0·594051
6·2	−0·039468:	−0·476330	−0·045948	+0·586750:
6·3	−0·080470	−0·474301	+0·006881	+0·574110:
6·4	−0·120310:	−0·467630:	+0·058730:	+0·556342
6·5	−0·158629:	−0·456446:	+0·109121:	+0·533698:
6·6	−0·195081:	−0·440918:	+0·157596	+0·506470:
6·7	−0·229342	−0·421254:	+0·203720:	+0·474985:
6·8	−0·261109	−0·397700	+0·247090	+0·439602:
6·9	−0·290104:	−0·370533	+0·287332	+0·400710
7·0	−0·316080	−0·340064	+0·324108	+0·358722
7·1	−0·338816	−0·306631	+0·357117	+0·314074
7·2	−0·358125	−0·270595	+0·386098	+0·267219:
7·3	−0·373853:	−0·232339	+0·410832:	+0·218624
7·4	−0·385881:	−0·192262	+0·431143	+0·168764:
7·5	−0·394126:	−0·150775:	+0·446898:	+0·118120
7·6	−0·398540:	−0·108301	+0·458011	+0·067173
7·7	−0·399113:	−0·065262:	+0·464439:	+0·016400:
7·8	−0·395871	−0·022087	+0·466186	−0·033728
7·9	−0·388874	+0·020803	+0·463298:	−0·082754:
8·0	−0·378220	+0·062993:	+0·455867:	−0·130238
8·1	−0·364039:	+0·104079:	+0·444026:	−0·175756
8·2	−0·346495:	+0·143673	+0·427948:	−0·218911
8·3	−0·325782:	+0·181404	+0·407844:	−0·259330
8·4	−0·302122:	+0·216924	+0·383963	−0·296671:
8·5	−0·275765:	+0·249909:	+0·356584	−0·330626
8·6	−0·246984	+0·280065	+0·326018	−0·360919:
8·7	−0·216073	+0·307126:	+0·292602	−0·387314
8·8	−0·183344:	+0·330861	+0·256697:	−0·409612:
8·9	−0·149126	+0·351070:	+0·218684:	−0·427656
9·0	−0·113758	+0·367594:	+0·178959	−0·441328:
9·1	−0·077588:	+0·380307:	+0·137930	−0·450556:
9·2	−0·040970	+0·389124	+0·096012:	−0·455307
9·3	−0·004259	+0·393996	+0·053627	−0·455591
9·4	+0·032191	+0·394916	+0·011193	−0·451460
9·5	+0·068031:	+0·391912:	−0·030873:	−0·443007:
9·6	+0·102922	+0·385054	−0·072164:	−0·430365

BESSEL FUNCTION DERIVATIVE, $\frac{\delta J_\nu(x)}{\delta \nu}$ (*contd.*)

x	$\nu=\frac{3}{2}$	$\nu=\frac{1}{2}$	$\nu=-\frac{1}{2}$	$\nu=-\frac{3}{2}$
9·7	+0·136533:	+0·374445	−0·112285:	−0·413703
9·8	+0·168551	+0·360225	−0·150855:	−0·393227:
9·9	+0·198677:	+0·342567:	−0·187514	−0·369179:
10·0	+0·226636:	+0·321679:	−0·221921:	−0·341829
10·1	+0·252174	+0·297795	−0·253765	−0·311475:
10·2	+0·275060:	+0·271177	−0·282758:	−0·278444:
10·3	+0·295094	+0·242112:	−0·308647:	−0·243082
10·4	+0·312101:	+0·210909	−0·331209:	−0·205753
10·5	+0·325940	+0·177892:	−0·350257	−0·166838:
10·6	+0·336498:	+0·143405	−0·365638	−0·126728:
10·7	+0·343697:	+0·107798	−0·377238:	−0·085823
10·8	+0·347491:	+0·071432:	−0·384981	−0·044523:
10·9	+0·347867:	+0·034673	−0·388827:	−0·003232:
11·0	+0·344845:	−0·002115:	−0·388777:	+0·037652:
11·1	+0·338479:	−0·038569:	−0·384869:	+0·077740
11·2	+0·328853:	−0·074333	−0·377178	+0·116652
11·3	+0·316084:	−0·109059	−0·365814	+0·154024
11·4	+0·300317:	−0·142414	−0·350924	+0·189510
11·5	+0·281726:	−0·174080	−0·332686:	+0·222785:
11·6	+0·260512	−0·203759	−0·311312:	+0·253550
11·7	+0·236898	−0·231174:	−0·287040	+0·281530
11·8	+0·211130:	−0·256073	−0·260134:	+0·306480:
11·9	+0·183474:	−0·278230	−0·230884	+0·328189:
12·0	+0·154213	−0·297448:	−0·199598:	+0·346475:
12·1	+0·123641:	−0·313561	−0·166603	+0·361194:
12·2	+0·092066:	−0·326433	−0·132238:	+0·372235:
12·3	+0·059803	−0·335963	−0·096854:	+0·379525
12·4	+0·027170	−0·342082	−0·060809:	+0·383027
12·5	−0·005511	−0·344755	−0·024464	+0·382741
12·6	−0·037920:	−0·343982:	+0·011820	+0·378703:
12·7	−0·069744:	−0·339798	+0·047686	+0·370987
12·8	−0·100674:	−0·332267:	+0·082783:	+0·359699:
12·9	−0·130414:	−0·321490:	+0·116771:	+0·344981
13·0	−0·158681	−0·307597	+0·149324	+0·327005
13·1	−0·185206:	−0·290748	+0·180131:	+0·305974
13·2	−0·209742:	−0·271130:	+0·208903	+0·282120
13·3	−0·232061	−0·248959	+0·235371	+0·255698
13·4	−0·251957:	−0·224470	+0·259292	+0·226988
13·5	−0·269251:	−0·197923:	+0·280449:	+0·196288:
13·6	−0·283790	−0·169595	+0·298655:	+0·163916
13·7	−0·295446:	−0·139778:	+0·313753:	+0·130200:
13·8	−0·304124:	−0·108779	+0·325617	+0·095481
13·9	−0·309756:	−0·076910:	+0·334154	+0·060105:
14·0	−0·312305:	−0·044495:	+0·339304:	+0·024425
14·1	−0·311765	−0·011858	+0·341043	−0·011209:
14·2	−0·308158:	+0·020677:	+0·339377:	−0·046449:
14·3	−0·301539	+0·052789	+0·334349:	−0·080954:
14·4	−0·291989	+0·084162:	+0·326033:	−0·114391
14·5	−0·279619	+0·114491:	+0·314535	−0·146441
14·6	−0·264567:	+0·143482:	+0·299990:	−0·176801:
14·7	−0·246997:	+0·170857	+0·282566:	−0·205187
14·8	−0·227095:	+0·196355	+0·262455	−0·231335
14·9	−0·205070	+0·219735:	+0·239874	−0·255006
15·0	−0·181150	+0·240781	+0·215064:	−0·275986

BESSEL FUNCTION DERIVATIVE, $\frac{\delta J\nu(x)}{\delta\nu}$ (*contd.*)

x	$\nu=\frac{3}{2}$	$\nu=\frac{1}{2}$	$\nu=-\frac{1}{2}$	$\nu=-\frac{3}{2}$
15·1	−0·155581	+0·259297	+0·188287:	−0·294089
15·2	−0·128624	+0·275116:	+0·159821:	−0·309159
15·3	−0·100551	+0·288099:	+0·129960	−0·321069:
15·4	−0·071644:	+0·298135:	+0·099008	−0·329727:
15·5	−0·042193:	+0·305142:	+0·067279:	−0·335070
15·6	−0·012491	+0·309071	+0·035093:	−0·337068:
15·7	+0·017170:	+0·309899:	+0·002773	−0·335727:
15·8	+0·046498	+0·307639:	−0·029362:	−0·331082:
15·9	+0·075205:	+0·302332:	−0·060994:	−0·323203
16·0	+0·103013:	+0·294048:	−0·091814	−0·312188
16·1	+0·129653	+0·282887:	−0·121520:	−0·298167:
16·2	+0·154868	+0·268978	−0·149826	−0·281300
16·3	+0·178417:	+0·252474	−0·176460:	−0·261769:
16·4	+0·200078:	+0·233554	−0·201169:	−0·239787
16·5	+0·219647:	+0·212420	−0·223720:	−0·215584:
16·6	+0·236942:	+0·189294:	−0·243904	−0·189414:
16·7	+0·251805	+0·164418:	−0·261534	−0·161547:
16·8	+0·264100:	+0·138048:	−0·276452	−0·132269
16·9	+0·273721:	+0·110455	−0·288527	−0·101875:
17·0	+0·280587	+0·081919	−0·297656	−0·070674
17·1	+0·284643	+0·052728	−0·303767	−0·038976:
17·2	+0·285863:	+0·023176	−0·306817:	−0·007098
17·3	+0·284251	−0·006441:	−0·306795:	+0·024646:
17·4	+0·279836	−0·035831	−0·303719:	+0·055945
17·5	+0·272675	−0·064701:	−0·297639	+0·086492:
17·6	+0·262853:	−0·092769	−0·288631	+0·115992:
17·7	+0·250480:	−0·119760:	−0·276803	+0·144161
17·8	+0·235691:	−0·145412:	−0·262288	+0·170729
17·9	+0·218644	−0·169478:	−0·245246	+0·195444
18·0	+0·199517	−0·191727:	−0·225861	+0·218073:
18·1	+0·178509:	−0·211949	−0·204338	+0·238407:
18·2	+0·155838	−0·229953	−0·180903:	+0·256259:
18·3	+0·131734:	−0·245571:	−0·155800:	+0·271468
18·4	+0·106444	−0·258663	−0·129288	+0·283899
18·5	+0·080222	−0·269110:	−0·101636:	+0·293446
18·6	+0·053331:	−0·276823:	−0·073127:	+0·300032
18·7	+0·026041:	−0·281740	−0·044048	+0·303609
18·8	−0·001377	−0·283825:	−0·014690	+0·304159:
18·9	−0·028651:	−0·283074	+0·014653	+0·301695:
19·0	−0·055513:	−0·279507	+0·043690:	+0·296258
19·1	−0·081699:	−0·273175	+0·072135	+0·287919
19·2	−0·106954	−0·264154	+0·099708	+0·276775:
19·3	−0·131032	−0·252547	+0·126140:	+0·262955
19·4	−0·153700	−0·238483:	+0·151175	+0·246607:
19·5	−0·174740:	−0·222114	+0·174572	+0·227909:
19·6	−0·193953	−0·203613:	+0·196106	+0·207058:
19·7	−0·211156:	−0·183176	+0·215574:	+0·184272
19·8	−0·226188:	−0·161014:	+0·232794	+0·159786
19·9	−0·238911	−0·137356:	+0·247605:	+0·133851:
20·0	−0·249208:	−0·112445:	+0·259874	+0·106732:

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS.

For the sake of convenience and simplicity the integral is denoted by $I_0(x)$ and those derived from it by repeated integration, by $I_n(x)$; *i.e.* $I_n(x)=\int_x^\infty I_{n-1}(x)\ dx$. As Dr. H. Jeffreys has pointed out, the most commonly used notation is Erf x, but the introduction of the symbol $I_n(x)$ need not lead to any confusion with the Bessel function with imaginary argument.

(A). For small positive values of x the series in ascending powers of the variable are convenient.

$$I_0(x)=\sqrt{\frac{\pi}{2}}-x\left(1-\frac{1}{2}\cdot\frac{x^2}{3}+\frac{1}{4}\cdot\frac{x^4}{5.2!}-\frac{1}{8}\cdot\frac{x^6}{7.3!}+\ldots\right)$$

whilst for large values of x the asymptotic series can be used.

$$I_0(x)=\frac{e^{-\frac{1}{2}x^2}}{x}\left(1-\frac{1}{x^2}+\frac{1.3}{x^4}-\frac{1.3.5}{x^6}+\frac{1.3.5.7}{x^8}-\ldots\right).$$

The series in the bracket, where the signs of the terms alternate, is an asymptotic series of the first kind (Stieltjes), and can therefore be employed to give results with an error considerably smaller than the least term. As shown in the 1926 Report, several places of decimals can be added to the result obtained when the divergent terms of the series are neglected. Intermediate values of $I_0(x)$ were obtained by calculating first differences over smaller intervals, 0·1, from $e^{-\frac{1}{2}x^2}$, the differential coefficient of the function, as in the case of the sine and cosine integrals.

Functions of higher order are found from the recurrence formula

$$nI_n(x)+xI_{n-1}(x)-I_{n-2}(x)=0$$

$$\text{where } I_{-1}(x)=e^{-\frac{1}{2}x^2}$$

Owing to the accumulation of errors, the formula is not very suitable for large positive values of x. The continued fraction

$$\frac{I_{n-2}(x)}{I_{n-1}(x)}=x+\frac{n}{x+}\;\frac{n+1}{x+}\;\frac{n+2}{x+}\;\frac{n+3}{x+}\cdots\cdot$$

giving the ratio of two functions, has been applied in these cases. For example, when $x=4$, the ratio of $I_{10}(x)$ to $I_{11}(x)$ is equal to 5·97. Ratios of lower order functions were then computed, with the following results:

$\rho\,(10,11)$	$=5{\cdot}97$	
$\rho\,(9,10)$	$=5{\cdot}84$	
$\rho\,(8,9)$	$=5{\cdot}711$:	
$\rho\,(7,8)$	$=5{\cdot}576$	
$\rho\,(6,7)$	$=5{\cdot}4348$	
$\rho\,(5,6)$	$=5{\cdot}2880$	
$\rho\,(4,5)$	$=5{\cdot}13464$:	
$\rho\,(3,4)$	$=4{\cdot}97377$	7
$\rho\,(2,3)$	$=4{\cdot}80421$	78
$\rho\,(1,2)$	$=4{\cdot}62445$	129:
$\rho\,(0,1)$	$=4{\cdot}43248$	3742
$\rho\,(-1,0)$	$=4{\cdot}22560$	71445.

The value of $I_{-1}(4)=0{\cdot}0^{3}3354626279$

and of $I_0(4)=0{\cdot}0^{4}7938803027$.

The ratio of these two values agrees with the last ratio in the foregoing table to ten places of decimals.

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_0(x)$	$I_1(x)$	$I_2(x)$
0·0	1·25331 41373	1·00000 00000	0·62665 70687
0·1	1·15348 05543	0·87966 44238	0·53275 70560
0·2	1·05463 95086	0·76927 07716	0·45039 26771
0·3	0·95775 40326	0·66867 12721	0·37857 63255
0·4	0·86372 96053	0·57762 45043	0·31633 99018
0·5	0·77338 89184	0·49580 24434	0.26274 38483
0·6	0·68745 06194	0·42279 98398	0·21688 53577
0·7	0·60651 29321	0·35814 54858	0·17790 55260
0·8	0·53104 27322	0·30131 48513	0·14499 54756
0·9	0·46137 03144	0·25174 35279	0·11740 05697
1·0	0·39768 97454	0·20884 09143	0· 9442 44156
1·1	0·34006 43843	0·17200 36039	0· 7543 02100
1·2	0·28843 68889	0·14062 79892	0· 5984 16509
1·3	0·24264 28317	0·11412 16771	0· 4714 23257
1·4	0·20242 69254	0· 9191 34033	0· 3687 40804
1·5	0·16746 08196	0· 7346 12379	0· 2863 44814
1·6	0·13736 14540	0· 5825 89740	0· 2207 35478
1·7	0·11170 90490	0· 4584 06932	0· 1688 99353
1·8	0· 9006 39538	0· 3578 35822	0· 1282 67529
1·9	0· 7198 17408	0· 2770 91491	0· 966 71788
2·0	0· 5702 61240	0· 2128 30353	0· 723 00267
2·1	0· 4477 94617	0· 1621 36557	0· 536 53923
2·2	0· 3485 07747	0· 1224 99132	0· 395 04828
2·3	0· 2688 13574	0· 917 82317	0· 288 57122
2·4	0· 2054 81753	0· 681 91420	0· 209 11172
2·5	0· 1556 53227	0· 502 36269	0· 150 31277

x	$I_3(x)$	$I_4(x)$	$I_5(x)$
0·0	0·33333 33333	0·15666 42672	0·06666 66667
0·1	0·27546 29061	0·12630 26913	0· 5256 65274
0·2	0·22639 74121	0·10127 82987	0· 4122 83505
0·3	0·18503 27915	0· 8076 66220	0· 3216 05610
0·4	0·15036 28478	0· 6404 86907	0· 2494 86743
0·5	0·12147 68397	0· 5050 13571	0· 1924 52322
0·6	0· 9755 62084	0· 3958 79082	0· 1476 06927
0·7	0· 7787 05345	0· 3084 90430	0· 1125 52409
0·8	0· 6177 28369	0· 2389 42890	0· 853 14811
0·9	0· 4869 43384	0· 1839 39163	0· 642 79627
1·0	0· 3813 88329	0· 1407 13957	0· 481 34874
1·1	0· 2967 67910	0· 1069 64350	0· 358 21425
1·2	0· 2293 93360	0· 807 86119	0· 264 90003
1·3	0· 1761 22179	0· 606 16106	0· 194 64248
1·4	0· 1342 98969	0· 451 80562	0· 142 09237
1·5	0· 1016 98386	0· 334 49309	0· 103 04885
1·6	0· 764 70992	0· 245 95473	0· 74 23647
1·7	0· 570 92677	0· 179 60450	0· 53 11982
1·8	0· 423 18090	0· 130 23742	0· 37 75071
1·9	0· 311 38365	0· 93 77224	0· 26 64328
2·0	0· 227 43273	0· 67 03431	0· 18 67282
2·1	0· 164 87773	0· 47 57400	0· 12 99447
2·2	0· 118 62837	0· 33 51647	0· 8 97843
2·3	0· 84 70312	0· 23 43851	0· 6 15891
2·4	0· 60 01536	0· 16 26872	0· 4 19409
2·5	0· 42 19359	0· 11 20720	0· 2 83512

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_6(x)$	$I_7(x)$	$I_8(x)$
0·0	0·02611 07112	$0{\cdot}0^2952$ 38095	$0{\cdot}0^2326$ 38389
0·1	0· 2017 43398	0· 722 12991	0· 243 15262
0·2	0· 1550 54381	0· 544 67518	0· 180 20110
0·3	0· 1185 30756	0· 408 63769	0· 132 83953
0·4	0· 901 15368	0· 304 91514	0· 97 39845
0·5	0· 681 31235	0· 226 26672	0· 71 02237
0·6	0· 512 19154	0· 166 96491	0· 51 50157
0·7	0· 382 83957	0· 122 50520	0· 37 13574
0·8	0· 284 48507	0· 89 36572	0· 26 62406
0·9	0· 210 14583	0· 64 80929	0· 18 97718
1·0	0· 154 29847	0· 46 72147	0. 13 44713
1·1	0· 112 60130	0· 33 47897	0. 9 47180
1·2	0· 81 66352	0· 23 84340	0· 6 63143
1·3	0· 58 85431	0· 16 87598	0· 4 61444
1·4	0· 42 14605	0· 11 86970	0. 3 19106
1·5	0· 29 98664	0· 8 29556	0· 2 19291
1·6	0· 21 19606	0· 5 76040	0. 1 49743
1·7	0· 14 88347	0· 3 97399	0· 1 01596
1·8	0· 10 38102	0· 2 72355	0· 68483
1·9	0· 7 19167	0· 1 85416	0· 45860
2·0	0· 4 94811	0· 1 25380	0· 30506
2·1	0· 3 38094	0· 84207	0· 20157
2·2	0· 2 29399	0· 56167	0· 13229
2·3	0· 1 54550	0· 37204	0· 8623
2·4	0· 1 03382	0. 24470	0· 5582
2·5	0· 68657	0· 15981	0· 3588

x	$I_9(x)$	$I_{10}(x)$	$I_{11}(x)$
0·0	$0{\cdot}0^2105$ 82011	$0{\cdot}0^3 32$ 63839	$0{\cdot}0^4 9$ 62001
0·1	0· 77 53496	0· 23 53991	0· 6 83463
0·2	0· 56 51500	0· 16 88981	0· 4 83064
0·3	0· 40 97620	0· 12 05467	0· 3 39635
0·4	0· 29 55064	0· 8 55782	0· 2 37523
0·5	0· 21 19506	0· 6 04248	0· 1 65217
0·6	0· 15 11822	0· 4 24306	0· 1 14294
0·7	0· 10 72335	0· 2 96294	0· 78630
0·8	0· 7 56294	0· 2 05737	0· 53791
0·9	0· 5 30331	0· 1 42042	0· 36590
1·0	0· 3 69715	0· 97500	0· 24747
1·1	0· 2 56222	0· 66534	0· 16640
1·2	0· 1 76508	0· 45133	0· 11123
1·3	0· 1 20858	0· 30433	0· 7390
1·4	0· 82247	0· 20396	0· 4881
1·5	0· 55624	0· 13585	0· 3204
1·6	0· 37383	0· 8993	0· 2090
1·7	0· 24965	0· 5916	0· 1355
1·8	0· 16595	0· 3861	0· 877
1·9	0· 10920	0· 2511	0· 559
2·0	0· 7152	0· 1620	0· 356
2·1	0· 4653	0· 1039	0· 225
2·2	0· 3007	0· 661	0· 141
2·3	0· 1930	0· 418	0· 88
2·4	0· 1231	0· 263	0· 55
2·5	0· 779	0· 164	0· 34

THE PROBABILITY INTEGRAL $\int_x^{\infty} e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_{12}(x)$	$I_{13}(x)$	$I_{14}(x)$	$I_{15}(x)$
0·0	$0{\cdot}0^{4}2$ 71987	$0{\cdot}0^{5}$74000	$0{\cdot}0^{5}$19428	$0{\cdot}0^{6}$4933
0·1	0· 1 90470	0· 51109	0· 13240	0· 3319
0·2	0· 1 32697	0· 35117	0· 8977	0· 2221
0·3	0· 91965	0· 24003	0· 6055	0· 1479
0·4	0· 63398	0· 16320	0· 4062	0· 980
0·5	0· 43470	0· 11037	0· 2711	0· 645
0·6	0· 29644	0· 7424	0· 1799	0· 423
0·7	0· 20104	0· 4966	0· 1188	0· 276
0·8	0· 13559	0· 3303	0· 780	0· 179
0·9	0· 9092	0· 2185	0· 509	0· 115
1·0	0· 6063	0· 1437	0· 330	0· 74
1·1	0· 4019	0· 940	0· 213	0· 47
1·2	0· 2649	0· 611	0· 137	0· 30
1·3	0· 1735	0· 395	0· 87	0· 19
1·4	0· 1130	0· 254	0· 55	0· 12
1·5	0· 732	0· 162	0· 35	0· 7
1·6	0· 471	0· 101	0· 22	0· 4
1·7	0· 301	0· 65	0· 14	0· 3
1·8	0· 190	0· 41	0· 8	0· 2
1·9	0· 121	0· 25	0· 5	0· 1
2·0	0· 76	0· 16	0· 3	0· 1
2·1	0· 47	0· 10	0· 2	0·
2·2	0· 29	0· 6	0· 1	0·
2·3	0· 18	0· 4	0· 1	0·
2·4	0· 11	0· 2	0·	0·
2·5	0· 7	0· 1	0·	0·

x	$I_{16}(x)$	$I_{17}(x)$	$I_{18}(x)$	$I_{19}(x)$	$I_{20}(x)$
0·0	$0{\cdot}0^{6}$1214	0.0^{7}290	$0{\cdot}0^{8}$67	$0{\cdot}0^{8}$15	$0{\cdot}0^{9}$3
0·1	0· 807	0. 190	0· 44	0· 10	0· 2
0·2	0· 533	0· 124	0· 28	0· 6	0· 1
0·3	0· 351	0· 81	0· 18	0· 4	0· 1
0·4	0· 229	0· 52	0· 12	0· 3	0· 1
0·5	0· 149	0· 34	0· 7	0· 2	
0·6	0· 97	0· 21	0· 5	0· 1	
0·7	0· 62	0· 14	0· 3	0· 1	
0·8	0· 40	0· 9	0· 2		
0·9	0· 25	0· 5	0· 1		
1·0	0· 16	0· 3	0· 1		
1·1	0· 10	0· 2			
1·2	0· 6	0· 1			
1·3	0· 4	0· 1			
1·4	0· 2				
1·5	0· 1				
1·6	0· 1				

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_0(x)$	$I_1(x)$	$I_2(x)$
2·5	0·01556 53227	$0{\cdot}0^{2}502$ 36269	$0{\cdot}0^{2}150$ 31277
2·6	0· 1168 38657	0· 366 94039	0· 107 17077
2·7	0· 869 04146	0· 265 72905	0· 75 78651
2·8	0· 640 47619	0· 190 77613	0· 53 15151
2·9	0· 467 69004	0· 135 77750	0· 36 96765
3·0	0· 338 36926	0· 95 79188	0· 25 49681
3·1	0· 242 54216	0· 66 98941	0· 17 43749
3·2	0· 172 23994	0· 46 43449	0· 11 82479
3·3	0· 121 17646	0· 31 90167	0· 7 95047
3·4	0· 84 45564	0· 21 72236	0· 5 29982
3·5	0· 58 31146	0· 14 65899	0· 3 50249
3·6	0· 39 88261	0· 9 80368	0· 2 29469
3·7	0· 27 02139	0· 6 49750	0· 1 49033
3·8	0· 18 13497	0· 4 26737	0· 95947
3·9	0· 12 05597	0· 2 77728	0· 61229
4·0	0· 7 93880	0· 1 79105	0· 38730
4·1	0· 5 17807	0· 1 14450	0· 24282
4·2	0· 3 34528	0· 72465	0· 15088
4·3	0· 2 14064	0· 45460	0· 9292
4·4	0· 1 35672	0· 28257	0· 5671
4·5	0· 85167	0· 17401	0· 3431
4·6	0· 52951	0· 10617	0· 2056
4·7	0· 32606	0· 6418	0· 1222
4·8	0· 19886	0· 3843	0· 719
4·9	0· 12011	0· 2280	0· 419
5·0	0· 7185	0· 1340	0· 242

x	$I_3(x)$	$I_4(x)$	$I_5(x)$	$I_6(x)$
2·5	$0{\cdot}0^{3}42$ 19359	$0{\cdot}0^{3}11$ 20720	$0{\cdot}0^{4}2$ 83512	$0{\cdot}0^{5}$ 68657
2·6	0· 29 43213	0· 7 66181	0· 1 90228	0· 45265
2·7	0· 20 36850	0· 5 19789	0· 1 26684	0· 29624
2·8	0· 13 98397	0· 3 49910	0· 83730	0· 19244
2·9	0· 9 52377	0· 2 33717	0· 54919	0· 12409
3·0	0· 6 43382	0· 1 54884	0· 35746	0· 7941
3·1	0· 4 31107	0· 1 01829	0· 23087	0· 5043
3·2	0· 2 86505	0· 66416	0· 14795	0· 3179
3·3	0· 1 88838	0· 42971	0· 9407	0· 1988
3·4	0· 1 23433	0· 27577	0· 5934	0· 1234
3·5	0· 80009	0· 17555	0· 3713	0· 760
3·6	0· 51426	0· 11083	0· 2305	0· 464
3·7	0· 32776	0· 6940	0· 1420	0· 281
3·8	0· 20713	0· 4310	0· 867	0· 169
3·9	0· 12978	0· 2654	0· 525	0· 101
4·0	0· 8062	0· 1621	0· 316	0· 60
4·1	0· 4965	0· 982	0· 188	0· 35
4·2	0· 3031	0· 589	0· 111	0· 20
4·3	0· 1835	0· 351	0· 65	0· 12
4·4	0· 1101	0· 207	0· 38	0· 7
4·5	0· 655	0· 121	0· 22	0· 4
4·6	0· 386	0· 70	0· 12	0· 2
4·7	0· 225	0· 40	0· 7	0· 1
4·8	0· 131	0· 23	0· 4	0· 1
4·9	0· 75	0· 13	0· 2	
5·0	0· 43	0· 7	0· 1	

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_7(x)$	$I_8(x)$	$I_9(x)$	$I_{10}(x)$	$I_{11}(x)$
2·5	$0{\cdot}0^{5}\,15981$	$0{\cdot}0^{6}\,3588$	$0{\cdot}0^{7}\,779$	$0{\cdot}0^{7}\,164$	$0{\cdot}0^{8}\,34$
2·6	0· 10363	0· 2290	0· 490	0· 102	0· 21
2·7	0· 6671	0· 1451	0· 306	0· 63	0· 12
2·8	0· 4264	0· 913	0· 190	0· 38	0· 8
2·9	0· 2705	0· 571	0· 117	0· 23	0· 5
3·0	0· 1703	0· 354	0· 71	0· 14	0· 3
3·1	0· 1065	0· 218	0· 43	0· 8	0· 2
3·2	0· 661	0· 133	0· 26	0· 5	0· 1
3·3	0· 407	0· 81	0· 16	0· 3	0· 1
3·4	0· 248	0· 49	0· 9	0· 2	
3·5	0· 151	0· 29	0· 5	0· 1	
3·6	0· 91	0· 17	0· 3	0· 1	
3·7	0· 54	0· 10	0· 2		
3·8	0· 32	0· 6	0· 1		
3·9	0· 19	0· 3	0· 1		
4·0	0· 11	0· 2			
4·1	0· 6	0· 1			
4·2	0· 4	0· 1			
4·3	0· 2				
4·4	0· 1				
4·5	0· 1				

x	$I_0(x)$	$I_1(x)$	$I_2(x)$	$I_3(x)$	$I_4(x)$
5·0	$0{\cdot}0^{6}\,7185$	$0{\cdot}0^{6}\,1340$	$0{\cdot}0^{7}\,242$	$0{\cdot}0^{8}\,43$	$0{\cdot}0^{9}\,7$
5·1	0· 4257	0· 780	0· 139	0· 24	0· 4
5·2	0· 2498	0· 450	0· 79	0· 13	0· 2
5·3	0· 1451	0· 257	0· 44	0· 7	0· 1
5·4	0· 835	0· 146	0· 25	0· 4	0· 1
5·5	0· 476	0· 82	0· 14	0· 2	
5·6	0· 269	0· 45	0· 7	0· 1	
5·7	0· 150	0· 25	0· 4	0· 1	
5·8	0· 83	0· 14	0· 2		
5·9	0· 46	0· 7	0· 1		
6·0	0· 25	0· 4	0· 1		
6·1	0· 13	0· 2			
6·2	0· 7	0· 1			
6·3	0· 4	0· 1			
6·4	0· 2				
6·5	0· 1				
6·6	0· 1				

(B). For negative values of x, $I_0(-x)=2I_0(0)-I_0(x)$, and again the recurrence formula will give functions of higher order. Generally

$$I_{2n}(-x)=2\sqrt{\frac{\pi}{2}}\left[\sum_{p=0}^{n}\frac{x^{2p}}{2^{n-p}(n-p)!(2p)!}\right]-I_{2n}(x)$$

$$\text{and } I_{2n+1}(-x)=2x\sqrt{\frac{\pi}{2}}\left[\sum_{p=0}^{n}\frac{x^{2p}}{2^{n-p}(n-p)!(2p+1)!}\right]+I_{2n+1}(x)$$

The results obtained from the recurrence formula were checked with those computed from

$$I_6(-x)+I_6(x)=\sqrt{\frac{\pi}{2}}(x^6+15x^4+45x^2+15)/360.$$

The polynomial in the bracket can be thrown into the form $(x^2+5)^3-10(3x^2+11)$, which only requires a table of squares and cubes.

A partial check was introduced by calculating $I_n(x+h)$, where $h=0{\cdot}1$, from $I_n(x)$ and its differential coefficients $I_{n-1}(x)$, $I_{n-2}(x)$, &c.

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_0(-x)$	$I_1(-x)$	$I_2(-x)$
0·0	1·25331 41373	1·00000 00000	0·62665 70687
0·1	1·35314 77204	1·13032 72512	0·73309 02227
0·2	1·45198 87660	1·27059 64265	0·85305 40257
0·3	1·54887 42421	1·42065 97545	0·98753 60842
0·4	1·64289 86693	1·58027 58141	1·13750 44975
0·5	1·73323 93563	1·74911 65807	1·30389 88233
0·6	1·81917 76553	1·92677 68046	1·48762 18690
0·7	1·90011 53425	2·11278 52780	1·68953 25186
0·8	1·97558 55424	2·30661 74710	1·91043 97596
0·9	2·04525 79602	2·50770 89750	2·15109 80189
1·0	2·10893 85292	2·71546 91889	2·41220 38591
1·1	2·16656 38904	2·92929 47060	2·69439 40335
1·2	2·21819 13857	3·14858 19188	2·99824 48441
1·3	2·26398 54430	3·37273 84341	3·32427 27036
1·4	2·30420 13492	3·60119 29878	3·67293 57661
1·5	2·33916 74550	3·83340 36498	4·04463 64649
1·6	2·36926 68206	4·06886 42135	4·43972 47811
1·7	2·39491 92256	4·30710 87601	4·85850 20589
1·8	2·41656 43208	4·54771 44766	5·30122 51893
1·9	2·43464 65338	4·79030 28709	5·76811 09943
2·0	2·44960 21506	5·03453 95845	6·25934 06598
2·1	2·46184 88129	5·28013 30325	6·77506 40906
2·2	2·47177 75000	5·52683 21174	7·31540 40791
2·3	2·47974 69172	5·77442 32634	7·88046 02115
2·4	2·48608 00993	6·02272 70012	8·47031 24510
2·5	2·49106 29519	6·27159 43135	9·08502 43678

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_3(-x)$	$I_4(-x)$	$I_5(-x)$
0·0	0·33333 33333	0·15666 42672	0·06666 66667
0·1	0·40121 20912	0·19330 28580	0·08410 84754
0·2	0·48040 24105	0·23728 36269	0·10557 18272
0·3	0·57230 68599	0·28980 70355	0·13184 97941
0·4	0·67842 58710	0·35221 87115	0·16386 26711
0·5	0·80035 53308	0·42601 91222	0·20267 29784
0·6	0·93978 33087	0·51287 29636	0·24950 14174
0·7	1·09848 60137	0·61461 81820	0·30574 37482
0·8	1·27832 30929	0·73327 45585	0·37298 85479
0·9	1·48123 23973	0·87105 17941	0·45303 58024
1·0	1·70922 43493	1·03035 70521	0·54791 62803
1·1	1·96437 60476	1·21380 19215	0·65991 16322
1·2	2·24882 52439	1·42420 87842	0·79157 51570
1·3	2·56476 43163	1·66461 65787	0·94575 31737
1·4	2·91443 43534	1·93828 59652	1·12560 69409
1·5	3·30011 94490	2·24870 39096	1·33463 50627
1·6	3·72414 12877	2·59958 77104	1·57669 63249
1·7	4·18885 40867	2·99488 85016	1·85603 29079
1·8	4·69663 99391	3·43879 42699	2·17729 39250
1·9	5·24990 45867	3·93573 24272	2·54555 92397
2·0	5·85107 36347	4·49037 19823	2·96636 35199
2·1	6·50258 92076	5·10762 53566	3·44572 04912
2·2	7·20690 70305	5·79264 98866	3·99014 73562
2·3	7·96649 39166	6·55084 90549	4·60668 93486
2·4	8·78382 56279	7·38787 34895	5·30294 44005
2·5	9·66138 50777	8·30962 17655	6·08708 78983

x	$I_6(-x)$	$I_7(-x)$	$I_8(-x)$
0·0	0·02611 07112	0·00952 38095	0·00326 38389
0·1	0· 3361 89509	0· 1249 57672	0· 435 85660
0·2	0· 4306 63321	0· 1631 21562	0· 579 10954
0·3	0· 5489 36623	0· 2118 82704	0· 765 62679
0·4	0· 6962 72967	0· 2738 76557	0· 1007 27949
0·5	0· 8789 26019	0· 3523 13256	0· 1318 85331
0·6	0·11042 89690	0· 4510 83998	0· 1718 67511
0·7	0·13810 64676	0· 5748 83251	0· 2229 35369
0·8	0·17194 42328	0· 7293 48477	0· 2878 65139
0·9	0·21313 06694	0· 9212 19150	0· 3700 50491
1·0	0·26304 55554	0·11585 16908	0. 4736 21558
1·1	0·32328 41195	0·14507 48805	0· 6035 83110
1·2	0·39568 31621	0·18091 35645	0· 7659 74299
1·3	0·48234 92841	0·22468 67490	0· 9680 52572
1·4	0·58568 92804	0·27793 88476	0·12185 04579
1·5	0·70844 27506	0·34247 13127	0·15276 87149
1·6	0·85371 69717	0·42037 76399	0·19079 01494
1·7	1·02502 40742	0·51408 19763	0·23737 04292
1·8	1·22632 05558	0·62638 15608	0·29422 59207
1·9	1·46204 91638	0·76049 32358	0·36337 32890
2·0	1·73718 31703	0·92010 42658	0·44717 39627
2·1	2·05727 30647	1·10942 77039	0·54838 39054
2·2	2·42849 56784	1·33326 25498	0·67020 91610
2·3	2·85770 57594	1·59705 89422	0·81636 76658
2·4	3·35249 00085	1·90698 86315	0·99115 78405
2·5	3·92122 35852	2·27002 09802	1·19953 45045

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_9(-x)$	$I_{10}(-x)$	$I_{11}(-x)$
0·0	0·00105 82011	0·00032 63839	0·00009 62001
0·1	0· 143 68471	0· 45 02251	0· 13 47154
0·2	0· 194 11528	0· 61 79326	0· 18 77036
0·3	0· 260 94612	0· 84 39106	0· 26 02395
0·4	0· 349 07526	0· 114 69096	0· 35 90470
0·5	0· 464 72880	0· 155 12177	0· 49 29906
0·6	0· 615 78278	0· 208 81448	0· 67 37013
0·7	0· 812 15334	0· 279 78610	0· 91 63669
0·8	0· 1066 26732	0· 373 16652	0· 124 07278
0·9	0· 1393 62732	0· 495 47695	0· 167 23242
1·0	0· 1813 48718	0· 654 97028	0· 224 40522
1·1	0· 2349 65581	0· 862 04525	0· 299 80960
1·2	0· 3031 44978	0· 1129 74827	0· 398 83161
1·3	0· 3894 81759	0· 1474 37886	0· 528 31910
1·4	0· 4983 66099	0· 1916 21712	0· 696 94227
1·5	0· 6351 38206	0· 2480 39446	0· 915 63398
1·6	0· 8062 68755	0· 3197 93150	0· 1198 12527
1·7	0·10195 68562	0· 4106 97085	0· 1561 59419
1·8	0·12844 31353	0· 5254 23564	0· 2027 44888
1·9	0·16121 13872	0· 6696 74925	0· 2622 26930
2·0	0·20160 57990	0· 8503 85561	0· 3378 93556
2·1	0·25122 59895	0·10759 58483	0· 4337 97519
2·2	0·31196 91893	0·13565 41378	0· 5549 16629
2·3	0·38607 82859	0·17043 47723	0· 7073 43875
2·4	0·47619 63832	0·21340 29160	0· 8985 12165
2·5	0·58542 85824	0·26631 05960	0·11374 59157

x	$I_{12}(-x)$	$I_{13}(-x)$	$I_{14}(-x)$
0·0	0·00002 71987	0·00000 74000	$0{\cdot}0^{2}000$ 19428
0·1	0· 3 86414	0· 1 06600	0· 28362
0·2	0· 5 46228	0· 1 52791	0· 41199
0·3	0· 7 68319	0· 2 17915	0· 59550
0·4	0· 10 75440	0· 3 09280	0· 85654
0·5	0· 14 98094	0· 4 36843	0· 1 22608
0·6	0· 20 76971	0· 6 14092	0. 1 74673
0·7	0· 28 66098	0· 8 59226	0· 2 47683
0·8	0· 39 36873	0· 11 96675	0· 3 49587
0·9	0· 53 83218	0· 16 59088	0· 4 91171
1·0	0· 73 28129	0· 22 89896	0· 6 87002
1·1	0· 99 31965	0· 31 46625	0· 9 56661
1·2	0· 134 02885	0· 43 05125	0· 13 26360
1·3	0· 180 09947	0· 58 64988	0· 18 31031
1·4	0· 240 99469	0· 79 56422	0· 25 17033
1·5	0· 321 15379	0· 107 48959	0· 34 45630
1·6	0· 426 24433	0· 144 62432	0. 46 97452
1·7	0· 563 47341	0· 193 80761	0. 63 78188
1·8	0· 741 97030	0· 258 69196	0· 86 25827
1·9	0· 973 25508	0· 343 95800	0. 116 19823
2·0	0· 1271 81056	0· 455 58128	0· 155 92665
2·1	0· 1655 77773	0· 601 16219	0· 208 44417
2·2	0· 2147 79830	0· 790 33250	0· 277 60927
2·3	0· 2776 03220	0· 1035 25483	0· 368 36559
2·4	0· 3575 38196	0· 1351 23372	0· 487 02449
2·5	0· 4588 96154	0· 1757 46119	0· 641 61532

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_{15}(-x)$	$I_{16}(-x)$	$I_{17}(-x)$
0·0	$0{\cdot}0^{2}000$ 04933	$0{\cdot}0^{3}00$ 01214	$0{\cdot}0^{3}00$ 00290
0·1	0· 7296	0· 1818	0· 440
0·2	0· 10735	0· 2709	0· 663
0·3	0· 15719	0· 4017	0· 996
0·4	0· 22903	0· 5926	0· 1487
0·5	0· 33210	0· 8701	0· 2209
0·6	0· 47926	0· 12714	0· 3268
0·7	0· 68840	0· 18492	0· 4811
0·8	0· 98423	0· 26770	0· 7049
0·9	0· 1 40076	0· 38577	0· 10282
1·0	0· 1 98460	0· 55341	0· 14929
1·1	0· 2 79930	0· 79037	0· 21581
1·2	0· 3 93117	0· 1 12381	0· 31057
1·3	0· 5 49689	0· 1 59102	0· 44501
1·4	0· 7 65351	0· 2 24283	0· 63491
1·5	0· 10 61160	0· 3 14836	0· 90201
1·6	0· 14 65224	0· 4 40113	0· 1 27612
1·7	0· 20 14912	0· 6 12721	0· 1 79796
1·8	0· 27 59712	0· 8 49582	0· 2 52292
1·9	0· 37 64898	0· 11 73321	0· 3 52600
2·0	0· 51 16231	0· 16 14070	0· 4 90845
2·1	0· 69 25966	0· 22 11809	0· 6 80633
2·2	0· 93 40486	0· 30 19375	0· 9 40183
2·3	0· 125 49971	0· 41 06343	0· 12 93798
2·4	0· 168 00617	0· 55 63996	0· 17 73777
2·5	0· 224 09997	0· 75 11658	0· 24 22891

x	$I_{18}(-x)$	$I_{19}(-x)$	$I_{20}(-x)$	$I_{21}(-x)$
0·0	$0{\cdot}0^{4}0$ 00067	$0{\cdot}0^{4}0$ 00015	$0{\cdot}0^{5}$ 00003	$0{\cdot}0^{5}$ 00001
0·1	0· 103	0· 24	0· 5	0· 1
0·2	0· 158	0· 37	0· 8	0· 2
0·3	0· 240	0· 56	0· 13	0· 3
0·4	0· 362	0· 86	0· 20	0· 4
0·5	0· 545	0· 131	0· 31	0· 7
0·6	0· 815	0· 198	0· 47	0· 11
0·7	0· 1214	0· 298	0· 71	0· 17
0·8	0· 1801	0· 447	0· 108	0· 25
0·9	0· 2657	0· 667	0· 163	0· 39
1·0	0· 3904	0· 991	0· 245	0· 59
1·1	0· 5710	0· 1466	0· 366	0· 89
1·2	0· 8314	0· 2160	0· 545	0· 134
1·3	0· 12053	0· 3167	0· 808	0· 201
1·4	0· 17398	0· 4624	0· 1194	0· 300
1·5	0· 25008	0· 6722	0· 1755	0· 445
1·6	0· 35794	0· 9731	0· 2568	0· 659
1·7	0· 51021	0· 14028	0· 3743	0· 971
1·8	0· 72428	0· 20140	0· 5434	0· 1425
1·9	0· 1 02403	0· 28798	0· 7856	0· 2082
2·0	0· 1 44209	0· 41014	0· 11312	0· 3030
2·1	0· 2 02286	0· 58181	0· 16223	0· 4393
2·2	0· 2 82654	0· 82212	0· 23176	0· 6343
2·3	0· 3 93449	0· 1 15723	0· 32981	0· 9123
2·4	0· 5 45614	0· 1 62276	0· 46754	0· 13071
2·5	0· 7 53827	0· 2 26708	0· 66030	0· 18656

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_0(-x)$	$I_1(x)$
2·5	2·49106 29519	6·27159 43135
2·6	2·49494 44089	6·52090 29180
2·7	2·49793 78601	6·77055 36320
2·8	2·50022 35127	7·02046 69303
2·9	2·50195 13743	7·27057 97714
3·0	2·50324 45821	7·52084 27427
3·1	2·50420 28531	7·77121 75455
3·2	2·50490 58752	8·02167 48237
3·3	2·50541 65100	8·27219 23230
3·4	2·50578 37182	8·52275 33573
3·5	2·50604 51600	8·77334 55511
3·6	2·50622 94485	9·02395 98254
3·7	2·50635 80608	9·27458 95911
3·8	2·50644 69250	9·52523 01173
3·9	2·50650 77150	9·77587 80438
4·0	2·50654 88866	10·02653 10090
4·1	2·50657 64939	10·27718 73709
4·2	2·50659 48218	10·52784 59999
4·3	2·50660 68683	10·77850 61269
4·4	2·50661 47074	11·02916 72340
4·5	2·50661 97579	11·27982 89760
4·6	2·50662 29795	11·53049 11250
4·7	2·50662 50140	11·78115 35325
4·8	2·50662 62861	12·03181 61026
4·9	2·50662 70735	12·28247 87737
5·0	2·50662 75561	12·53314 15072

x	$I_2(-x)$	$I_3(-x)$
2·5	9·08502 43678	9·66138 50777
2·6	9·72464 59978	10·60166 08374
2·7	10·38921 63333	11·60714 59106
2·8	11·07876 54588	12·68033 67383
2·9	11·79331 63557	13·82373 24010
3·0	12·53288 64051	15·03983 39860
3·1	13·29748 86220	16·33114 40913
3·2	14·08713 26555	17·70016 64405
3·3	14·90182 55880	19·14940 55878
3·4	15·74157 25665	20·68136 66945
3·5	16·60637 72945	22·29855 53606
3·6	17·49624 24100	24·00347 75005
3·7	18·41116 97739	25·79863 92515
3·8	19·35116 06854	27·68654 69073
3·9	20·31621 60429	29·66970 68704
4·0	21·30633 64614	31·75062 56182
4·1	22·32152 23574	33·93180 96788
4·2	23·36177 40107	36·21576 56150
4·3	24·42709 16071	38·60500 00124
4·4	25·51747 52686	41·10201 94720
4·5	26·63292 50749	43·70933 06043
4·6	27·77344 10773	46·42944 00268
4·7	28·93902 33085	49·26485 43608
4·8	30·12967 17892	52·21808 02302
4·9	31·34538 65323	55·29162 42607
5·0	32·58616 75460	58·48799 30790

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_4(-x)$	$I_5(-x)$
2·5	8·30962 17655	6·08708 78983
2·6	9·32224 10438	6·96789 75103
2·7	10·43212 75730	7·95477 80715
2·8	11·64592 70815	9·05778 65133
2·9	12·97053 50796	10·28765 68264
3·0	14·41309 70908	11·65582 50517
3·1	15·98100 88262	13·17445 42905
3·2	17·68191 63162	14·85645 97305
3·3	19·52371 60069	16·71553 36821
3·4	21·51455 48320	18·76617 06246
3·5	23·66283 02642	21·02369 22570
3·6	25·97719 03530	23·50427 25542
3·7	28·46653 37511	26·22496 28261
3·8	31·14000 97333	29·20371 67788
3·9	34·00707 28376	32·45941 55774
4·0	37·07720 97335	36·01189 29104
4·1	40·36048 55101	39·88196 00540
4·2	43·86699 73984	44·09143 09377
4·3	47·60714 79151	48·66314 72095
4·4	51·59159 02363	53·62100 33023
4·5	55·83122 81986	58·98997 14996
4·6	60·33721 63002	64·79612 70015
4·7	65·12095 97010	71·06667 29911
4·8	70·19411 42235	77·82996 57006
4·9	75·56858 63524	85·11553 94775
5·0	81·25653 32352	92·95413 18510

x	$I_6(-x)$	$I_7(-x)$
2·5	3·92122 35852	2·27002 09802
2·6	4·57312 90951	2·69400 47368
2·7	5·31833 80610	3·18775 58338
2·8	6·16795 48865	3·76115 14565
2·9	7·13412 33127	4·42523 06333
3·0	8·23009 53743	5·19230 15964
3·1	9·47030 28545	6·07605 61628
3·2	10·87043 12423	7·09169 13865
3·3	12·44749 61930	8·25603 87313
3·4	14·21992 24926	9·58770 10142
3·5	16·20762 55273	11·10719 73718
3·6	18·43209 52580	12·83711 64976
3·7	20·91648 27013	14·80227 84030
3·8	23·68568 89154	17·02990 49511
3·9	26·76645 64936	19·54979 94146
4·0	30·18746 35625	22·39453 53087
4·1	33·97942 02886	25·59965 47482
4·2	38·17516 78894	29·20387 65819
4·3	42·80978 01527	33·24931 45523
4·4	47·92066 74611	37·78170 57330
4·5	53·54768 33245	42·85064 94943
4·6	59·73323 34179	48·50985 72462
4·7	66·52238 71265	54·81741 32123
4·8	73·96299 15977	61·83604 64814
4·9	82·10578 82987	69·63341 45916
5·0	91·00453 20817	78·28239 88942

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_8(-x)$	$I_9(-x)$
2·5	1·19953 45045	0·58542 85824
2·6	1·44719 26763	0·71741 17438
2·7	1·74065 98515	0·87639 30481
2·8	2·08739 73706	1·06731 82327
2·9	2·49591 15187	1·29593 04486
3·0	2·97587 50204	1·56888 07397
3·1	3·53825 96199	1·89385 12205
3·2	4·19548 04599	2·27969 20954
3·3	4·96155 30008	2·73657 37371
3·4	5·85226 32426	3·27615 51155
3·5	6·88535 20411	3·91176 99462
3·6	8·08071 43312	4·65863 20100
3·7	9·46061 40990	5·53406 11744
3·8	11·04991 59662	6·55773 17358
3·9	12·87633 42763	7·75194 47880
4·0	14·97070 05996	9·14192 64119
4·1	17·36725 05945	10·75615 35762
4·2	20·10393 11917	12·62670 97319
4·3	23·22272 90909	14·78967 21826
4·4	26·77002 15858	17·28553 34123
4·5	30·79695 07561	20·15965 86552
4·6	35·35982 20938	23·46278 20975
4·7	40·52052 86530	27·25154 42091
4·8	46·34700 18385	31·58907 28118
4·9	52·91368 99747	36·54561 06075
5·0	60·30206 58191	42·19919 19989

x	$I_{10}(-x)$	$I_{11}(-x)$
2·5	0·26631 05960	0·11374 59157
2·6	0·33124 63210	0·14351 38344
2·7	0·41069 21081	0·18047 83400
2·8	0·50758 88422	0·22623 33628
2·9	0·62541 09820	0·28269 29360
3·0	0·76825 17240	0·35214 87192
3·1	0·94091 98403	0·43733 66114
3·2	1·14904 95165	0·54151 36862
3·3	1·39922 46333	0·66854 68206
3·4	1·69911 90635	0·82301 45392
3·5	2·05765 46853	1·01032 37586
3·6	2·48517 89567	1·23684 32958
3·7	2·99366 40444	1·51005 61944
3·8	3·59692 96562	1·83873 31300
3·9	4·31089 18950	2·23312 93799
4·0	5·15384 06247	2·70520 80828
4·1	6·14674 80257	3·26889 27710
4·2	7·31361 12066	3·94035 24363
4·3	8·68183 19476	4·73832 26870
4·4	10·28263 68600	5·68446 68724
4·5	12·15154 14704	6·80378 13884
4·6	14·32886 19742	8·12504 97436
4·7	16·86027 86436	9·68135 03485
4·8	19·79745 51335	11·51062 34048
4·9	23·19871 81951	13·65630 27058
5·0	27·12980 25813	16·16801 86278

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_{12}(-x)$	$I_{13}(-x)$
2·5	0·04588 96154	0·01757 46119
2·6	0· 5869 85242	0· 2277 92306
2·7	0· 7483 19688	0· 2942 49735
2·8	0· 9508 68548	0· 3788 28120
2·9	0·12043 50414	0· 4861 18889
3·0	0·15205 81568	0· 6217 87069
3·1	0·19138 86113	0· 7928 01005
3·2	0·24015 77760	0·10077 06592
3·3	0·30045 24285	0·12769 53719
3·4	0·37478 07081	0·16132 83805
3·5	0·46614 89867	0·20321 88625
3·6	0·57815 12351	0·25524 52109
3·7	0·71507 26637	0·31967 88500
3·8	0·88200 96292	0·39925 92093
3·9	1·08500 80397	0·49728 15950
4·0	1·33122 27463	0·61769 99283
4·1	1·62910 06989	0·76524 65874
4·2	1·98859 09533	0·94557 18800
4·3	2·42138 49585	1·16540 60007
4·4	2·94119 09249	1·43274 66878
4·5	3·56404 64765	1·75707 61948
4·6	4·30867 42329	2·14961 16319
4·7	5·19688 54401	2·62359 32244
4·8	6·25403 72897	3·19461 55689
4·9	7·50955 01211	3·88100 75615
5·0	8·99749 13100	4·70426 73214

x	$I_{14}(-x)$	$I_{15}(-x)$
2·5	0·00641 61532	0·00224 09997
2·6	0· 842 31803	0· 297 86333
2·7	0· 1101 99570	0· 394 52572
2·8	0· 1436 84806	0· 520 76372
2·9	0· 1867 21085	0· 685 07336
3·0	0· 2418 53055	0· 898 23082
3·1	0· 3122 54945	0· 1173 86089
3·2	0. 4018 74204	0· 1529 13603
3·3	0· 5156 05111	0· 1985 63372
3·4	0· 6594 98001	0· 2570 38467
3·5	0· 8410 10718	0· 3317 15076
3·6	0·10693 09995	0· 4267 97873
3·7	0·13556 31720	0· 5475 08391
3·8	0·17137 10446	0· 7003 12786
3·9	0·21602 90186	0· 8931 96512
4·0	0·27157 30328	0·11359 94706
4·1	0·34047 22648	0·14407 88582
4·2	0·42571 37749	0·18223 79823
4·3	0·53090 21972	0·22988 56966
4·4	0·66037 68822	0·28922 69980
4·5	0·81934 92395	0·36294 31848
4·6	1·01406 34100	0·45428 68879
4·7	1·25198 38282	0·56719 44811
4·8	1·54201 37157	0·70641 87603
4·9	1·89474 90837	0·87768 52048
5·0	2·32277 34226	1·08787 56290

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_0(-x)$	$I_1(-x)$
5·0	2·50662 75561	12·53314 15072
5·1	2·50662 78489	12·78380 42786
5·2	2·50662 80249	13·03446 70731
5·3	2·50662 81295	13·28512 98813
5·4	2·50662 81911	13·53579 26976
5·5	2·50662 82270	13·78645 55186
5·6	2·50662 82478	14·03711 83425
5·7	2·50662 82596	14·28778 11679
5·8	2·50662 82663	14·53844 39942
5·9	2·50662 82701	14·78910 68211
6·0	2·50662 82722	15·03976 96482
6·1	2·50662 82733	15·29043 24755
6·2	2·50662 82739	15·54109 53028
6·3	2·50662 82743	15·79175 81302
6·4	2·50662 82744	16·04242 09577
6·5	2·50662 82745	16·29308 37851
6·6	2·50662 82746	16·54374 66126
6·7	2·50662 82746	16·79440 94400
6·8	2·50662 82746	17·04507 22675
6·9	2·50662 82746	17·29573 50950
7·0	2·50662 82746	17·54639 79224
8·0	2·50662 82746	20·05302 61970
9·0	2·50662 82746	22·55965 44717
10·0	2·50662 82746	25·06628 27463

x	$I_2(-x)$	$I_3(-x)$
5·0	32·58616 75460	58·48799 30790
5·1	33·85201 48350	61·80969 33124
5·2	35·14292 84024	65·25923 15886
5·3	36·45890 82501	68·83911 45356
5·4	37·79995 43790	72·55184 87813
5·5	39·16606 67897	76·39994 09541
5·6	40·55724 54828	80·38589 76820
5·7	41·97349 04583	84·51222 55934
5·8	43·41480 17164	88·78143 13164
5·9	44·88117 92572	93·19602 14794
6·0	46·37262 30806	97·75850 27106
6·1	47·88913 31868	102·47138 16383
6·2	49·43070 95757	107·33716 48907
6·3	50·99735 22474	112·35835 90962
6·4	52·58906 12018	117·53747 08830
6·5	54·20583 64389	122·87700 68793
6·6	55·84767 79588	128·37947 37135
6·7	57·51458 57614	134·04737 80138
6·8	59·20655 98468	139·88322 64085
6·9	60·92360 02149	145·88952 55259
7·0	62·66570 68658	152·06878 19943
8·0	81·46541 89255	223·92545 92004
9·0	102·77175 92599	315·83516 26035
10·0	126·58472 78689	430·30452 04783

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_4(-x)$	$I_5(-x)$
5·0	81·25653 32352	92·95413 18510
5·1	87·27036 26821	101·37770 85982
5·2	93·62273 31658	110·41948 88101
5·3	100·32655 38221	120·11396 99586
5·4	107·39498 44495	130·49695 29618
5·5	114·84143 55093	141·60556 72510
5·6	122·67956 81255	153·47829 58370
5·7	130·92329 40851	166·15500 03757
5·8	139·58677 58379	179·67694 62353
5·9	148·68442 64964	194·08682 75617
6·0	158·23090 98361	209·42879 23454
6·1	168·24114 02951	225·74846 74877
6·2	178·73028 29746	243·09298 38666
6·3	189·71375 36384	261·51100 14036
6·4	201·20721 87132	281·05273 41295
6·5	213·22659 52886	301·76997 52510
6·6	225·78805 11170	323·71612 22171
6·7	238·90800 46135	346·94620 17849
6·8	252·60312 48562	371·51689 50862
6·9	266·89033 15860	397·48656 26938
7·0	281·78679 52064	424·91526 96879
8·0	468·21727 31321	793·93272 88515
9·0	736·32205 56729	1388·54673 27318
10·0	1107·40748 31630	2300·87587 04217

x	$I_6(-x)$	$I_7(-x)$
5·0	91·00453 20817	78·28239 88942
5·1	100·71611 27555	87·86141 19501
5·2	111·30067 91631	98·45471 72083
5·3	122·82176 57671	110·15276 12177
5·4	135·34642 17405	123·05251 86229
5·5	148·94534 25650	137·25785 01941
5·6	163·69300 41354	152·87987 41422
5·7	179·66779 93711	170·03735 09702
5·8	196·95217 73338	188·85708 21102
5·9	215·63278 48517	209·47432 25981
6·0	235·80061 06514	232·03320 80363
6·1	257·55113 19950	256·68719 60939
6·2	280·98446 38246	283·59952 27970
6·3	306·20551 04135	312·94367 38583
6·4	333·32411 95236	344·90387 12972
6·5	362·45523 90701	379·67557 56009
6·6	393·71907 62916	417·46600 36774
6·7	427·24125 94287	458·49466 28510
6·8	463·15300 19070	502·99390 11506
6·9	501·59126 90289	551·20947 41419
7·0	542·69894 71702	603·40112 85542
8·0	1136·61318 39906	1412·40545 72538
9·0	2205·54044 17099	3034·05867 25887
10·0	4019·36103 12300	6070·64088 32460

THE PROBABILITY INTEGRAL $\int_x^\infty e^{-\frac{1}{2}t^2}dt$ AND ITS INTEGRALS—*contd.*

x	$I_8(-x)$	$I_9(-x)$
5·0	60·30206 58191	42·19919 19989
5·1	68·60116 42126	48·63637 21594
5·2	77·90815 10808	55·95301 14254
5·3	88·32892 50276	64·25511 82071
5·4	99·97875 27880	73·65975 37420
5·5	112·98293 98291	84·29600 21393
5·6	127·47753 74165	96·30600 92972
5·7	143·61008 74877	109·84609 44055
5·8	161·54040 66966	125·08793 78834
5·9	181·44141 10226	142·21984 97368
6·0	203·49998 23586	161·44812 24654
6·1	227·91787 85210	182·99847 27858
6·2	254·91268 81458	207·11757 65890
6·3	284·71883 19651	234·07470 16932
6·4	317·58861 19782	264·16344 31064
6·5	353·79331 00595	297·70356 56653
6·6	393·62433 75703	335·04295 90713
6·7	437·39443 75663	376·55971 05050
6·8	485·43894 12163	422·66430 01580
6·9	538·11708 00760	473·80192 51851
7·0	595·81335 58812	530·45495 77470
8·0	1554·48210 52526	1538·69581 10305
9·0	3689·00856 18760	4026·12619 21637
10·0	8090·72123 29612	9664·20591 25398

x	$I_{10}(-x)$	$I_{11}(-x)$
5·0	27·12980 25813	16·16801 86278
5·1	31·66466 62226	19·10237 90813
5·2	36·88638 10493	22·52383 57165
5·3	42·88810 51525	26·50564 32287
5·4	49·77414 22995	31·13092 01963
5·5	57·66109 51595	36·49382 05015
5·6	66·67911 89481	42·70082 50369
5·7	76·97328 25599	49·87216 40906
5·8	88·70504 46420	58·14338 15279
5·9	102·05385 24470	67·66705 26522
6·0	117·21887 17151	78·61466 84323
6·1	134·42085 62514	91·17869 96290
6·2	153·90416 62997	105·57485 52407
6·3	175·93894 52632	122·04455 06229
6·4	200·82346 47859	140·85760 16124
6·5	228·88664 86884	162·31516 20127
6·6	260·49078 67441	186·75292 28711
6·7	296·03444 97950	214·54459 31029
6·8	335·95561 82291	246·10568 21923
6·9	380·73503 63853	281·89760 69313
7·0	430·89980 60110	322·43214 54386
8·0	1386·40485 93497	1148·17588 05298
9·0	3992·41442 91349	3632·53236 85798
10·0	10473·27803 58359	10399·72602 46272

Absorption Spectra.—*Report of Committee* (Prof. I. M. Heilbron, *Chairman*; Prof. E. C. C. Baly, *Secretary*; Prof. A. W. Stewart).

List of Organic Compounds, the Absorption Spectra of which have been measured in the Visible and Ultra-violet since the last list which was published in the British Association Report for 1922.

A

Acacetin. Hattori. Acta Phytochim., **2**, 99 (1925).
,, reduction product of. Tasaki. Acta Phytochim., **3**, 1 (1927).
Acaciin. Hattori. Acta Phytochim., **2**, 99 (1925).
,, Tasaki. Acta Phytochim., **2**, 129 (1925).
Acetaldehyde. Lüthy. Compt. rend., **176**, 1547 (1923).
,, Schou. Compt. rend., **182**, 965 (1926).
,, phenylhydrazone. Stevens and Ward. Trans., **125**, 1324 (1924).
,, phenylmethylhydrazone. Stevens and Ward. Trans., **125**, 1324 (1924).
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Acetic acid. Holmes and Patrick. J. phys. Chem., **26**, 25 (1922).
,, ,, ethyl ester. Ley and Hünecke. Ber., **59**, 510 (1926).
,, ,, methyl ester. Ley and Hünecke. Ber., **59**, 510 (1926).
,, ,, sodium salt. Ley. Zeit. phys. Chem., **94**, 405 (1920).
,, ,, ,, ,, Ley and Hünecke. Ber., **59**, 510 (1926).
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,, Holmes and Patrick. J. phys. Chem., **26**, 25 (1922).
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,, Purvis. Trans., **127**, 9 (1925).
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,, Scheibe. Ber., **58**, 586 (1925), **60**, 1406 (1927).
,, vapour. Porter and Iddings. J. Amer. Chem. Soc., **48**, 40 (1926).
,, and chloroform, molecular compound of. Scheibe, May and Fischer. Ber, **57**, 1330 (1924).
Acetophenone. Scheibe. Ber., **59**, 2617 (1926), **60**, 1406 (1927).
,, Tasaki. Acta Phytochim. **3**, 259 (1927).
4-Acetoxyacetophenone. Tasaki. Acta Phytochim., **3**, 259 (1927).
o-Acetoxybenzoic acid. Purvis. Trans., **127**, 2771 (1925).
,, ,, lithium salt. Purvis. Trans., 1926, 775.
4-Acetoxychalkone. Shibata and Nagai. Acta Phytochim., **2**, 25 (1924).
4′-Acetoxyethochalkone. Shibata and Nagai. Acta Phytochim., **2**, 25 (1924).
Acetylacetone. Acly and French. J. Amer. Chem. Soc., **49**, 847 (1927).
,, Grossmann. Zeit. phys. Chem., **109**, 305 (1924).
,, copper salt. Acly and French. J. Amer. Chem. Soc., **49**, 847 (1927).
,, dianilhydrochloride. Scheibe. Ber., **56**, 137 (1923).
,, dioxime. Acly and French. J. Amer. Chem. Soc., **49**, 847 (1927).
,, monoxime anhydride. Acly and French. J. Amer. Chem. Soc., **49**, 847 (1927).
Acetylacetoneurea, dibenzal compound. Scheibe. Ber., **56**, 137 (1923).
Acetylacetophenone. Tasaki. Acta Phytochim., **3**, 259 (1927).
p-Acetylaminoazobenzene. Uemura and Tabei. Bull. Chem. Soc., Japan, **3**, 105 (1928).
m-Acetylamino-*o*-hydroxyazobenzene. Uemura and Tabei. Bull. Chem. Soc., Japan, **3**, 105 (1928).
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,, ,, Ley and Arends. Ber., **61**, 212 (1928).
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p-Aminoazobenzene-*p'*-sulphonic acid. Thiel, Dassler and Wülfken. Fortschritte Chem. Phys., **18**, 79 (1924).
o-Aminobenzoic acid. Hünecke. Ber., **60**, 1451 (1927).
,, ,, sodium salt. Hünecke. Ber., **60**, 1451 (1927).
α-Amino-*n*-butyric acid. Ley and Arends. Ber., **61**, 212 (1928).
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1-Amino-2 : 5-dimethylpyrrole-4-carboxylic acid, ethyl ether. Korschun and Roll. Bull. Soc. Chim., **37**, 130 (1925).
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2:4:4′-Trioxybenzophenone. Tasaki. Acta Phytochim., **2**, 49 (1925).
2:4:2′-Trioxybenzophenone. Tasaki. Acta Phytochim., **2**, 49 (1925).
2:3:4-Trioxyphenylacetophenone. Tasaki. Acta Phytochim., **3**, 259 (1927).
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Photographs of Geological Interest.—*Twenty-fourth Report of Committee* (Professors E. J. GARWOOD, *Chairman, and* S. H. REYNOLDS, *Secretary*; Mr. C. V. CROOK, Mr. J. F. JACKSON, Mr. A. S. REID, Prof. W. W. WATTS, *and* Mr. R. J. WELCH).

IN the present report 521 photographs are listed, bringing the number in the collection up to 8,145. Of these 265 are from the Reader series, and, adding them to the 829 listed in the two previous reports, we have no less than 1,094 additions to the collection from this source. The Committee are further in possession of several hundred of Mr. Reader's negatives, which practically duplicate subjects in the series, and have consequently not been listed, while several hundred negatives were destroyed as being of little or no geological interest. Probably not less than 2,000 of Mr. Reader's negatives have been dealt with in all.

The Committee deeply regret to have to record the death of one of their number—Mr. Godfrey Bingley—who contributed an unsurpassed series of photographs to the collection.

The following have kindly helped in the description of photographs included in the present list: Mr. G. Barrow, Dr. H. H. Bemrose, Dr. F. W. Bennett, Prof. A. Morley Davies, Miss M. S. Johnston, Mr. H. W. Monckton, Mr. R. S. Herries, Dr. R. L. Sherlock, Dr. L. J. Wills, and Mr. G. W. Young. The Committee are again greatly indebted to Miss M. S. Johnston for much kind help.

The Committee have received from the National Museum of Wales, through Dr. F. J. North, a valuable series of photographs taken by Mr. F. F. Miskin and illustrating Somerset, Westmorland, Glamorgan, Pembroke and other parts of Wales. From the same source comes a set illustrating river development in Brecon taken by Mr. W. E. Howarth. The Committee have acquired, partly by purchase from Mr. A. J. Lewis and partly by gift from Mr. J. Challinor, an extensive series of photographs illustrating the effects at Aberystwyth of the storm of October 28, 1927. The Secretary contributes sets from Argyle, Bute and the Isle of Eigg, and Mr. L. G. Anniss a series illustrating the geology of Saltern Cove, near Paignton. Mr. J. F. Jackson contributes sets from Dorset and the Isle of Wight.

The photographs published by the Committee as prints or lantern slides are obtainable from the Secretary at the following rates :—

		£	s.	d.
1st issue—22 Bromide Prints, with letterpress,	unmounted..	1	13	0
,, 22 ,, ,, ,,	mounted on cards.. ..	2	4	0
,, 22 Lantern Slides ,, ,,	.. ..	2	4	0
2nd issue—25 Bromide Prints ,, ,,	unmounted..	1	18	6
,, 25 ,, ,, ,,	mounted on cards.. ..	2	10	0
,, 25 Lantern Slides ,, ,,	.. ..	2	10	0
3rd issue—23 Bromide Prints ,, ,,	unmounted..	1	14	6
,, 23 ,, ,, ,,	mounted on cards.. ..	2	6	0
,, 23 Lantern Slides ,, ,,	.. ..	2	6	0

The Reader negatives being the property of the Committee, prints (¼-plate) may be obtained through the Secretary at 4*d*. each, lantern slides at 1*s*. It is hoped before the publication of the next report to publish a fourth series of geological photographs.

The Committee recommend that they be reappointed.

TWENTY-FOURTH LIST OF GEOLOGICAL PHOTOGRAPHS.

FROM JUNE 30, 1927, TO JUNE 30, 1928.

List of the geological photographs received and registered by the Secretary of the Committee since the publication of the last report.

Contributors are asked to affix the registered numbers, as given below, to their negatives, for convenience of future reference. Their own numbers are added in order to enable them to do so. Copies of photographs desired can, in most instances, be obtained from the photographer direct. The cost at which copies may be obtained depends on the size of the print and on local circumstances over which the Committee have no control.

The Committee do not assume the copyright of any photograph included in this list. Inquiries respecting photographs, and applications for permission to reproduce them, should be addressed to the photographers direct.

Copies of photographs should be sent, unmounted, to

Professor S. H. Reynolds,
The University, Bristol,

accompanied by descriptions written on a form prepared for the purpose, copies of which may be obtained from him.

The size of the photographs is indicated, as follows:—

L=Lantern size.	1/1=Whole plate.
1/4=Quarter-plate.	10/8=10 inches by 8.
1/2=Half-plate.	12/10=12 inches by 10, &c.
P.C.=post card.	E signifies Enlargement.

ACCESSIONS.

England.

Berkshire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

7624	Collier's Waterloo Pit, Reading .	London Clay and Reading Beds. 1907.
7625	Pit near St. Peter's Church, Caversham	Chalk section (zone of M. cor-anguinum). 1907.
7626	Toot's Pit, Caversham . .	Gravel with palæoliths. 1907.

Buckinghamshire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

7627	(1) Robinson's Gravel Pit, Soulbury	Glacial-outwash gravels. 1914.
7628	(2) Robinson's Gravel Pit, Soulbury	Glacial-outwash gravels with decalcification pipes. 1914.
7629	(3) Robinson's Gravel Pit, Soulbury	Glacial-outwash gravels with decalcification pipes. 1914.
7630	(4) Robinson's Gravel Pit, Soulbury	Glacial-outwash gravels.
7631	(6) Warren Farm, Stewkley .	Lower Purbeck Beds, Portland Stone, Portland Sand. 1914.
7632	(7) Warren Farm, Stewkley .	Lower Purbeck on Portland Stone. 1914.
7633	(8) Warren Farm, Stewkley .	Succession—Lower Purbeck to Portland Sand. 1914.
7634	(9) Warren Farm, Stewkley .	Lower Purbeck on Portland Stone. 1914.
7635	(10) Warren Farm, Stewkley .	Portland Stone on Portland Sand. 1914.
7636	(11) Hedges' Brickfield, Stewkley.	Kimmeridge Clay glacially contorted. 1914.
7637	(12) Hedges' Brickfield, Stewkley.	Kimmeridge Clay, glacially contorted. 1914.
7638	(13) Hedges' Brickfield, Stewkley.	Kimmeridge Clay, glacially contorted. 1914.
7639	Cowcroft, Chesham . . .	Reading pebble drift lying horizontally on inclined Reading Beds. 1915.
7640	Cowcroft, Chesham . . .	Reading pebble drift lying horizontally on inclined Reading Beds. 1915.
7641	Cowcroft, Chesham . . .	*Ditrupa* band in London Clay. 1915.
7642	Cowcroft, Chesham . . .	*Ditrupa* band in London Clay. 1915.
7643	Bugle Pit, Hartwell . . .	Purbeck Beds on Portland Stone. 1912.
7644	Bugle Pit, Hartwell . . .	Purbeck Beds on Portland Stone. 1912.
7645	Hartwell, 2 m. S.W. of Aylesbury.	Concretion from Reading Beds built into wall. 1912.
7646	Locke's Brickfield, Hartwell .	Hartwell Clay capped by alluvium. 1912.
7647	(1) Windmill Pit, Stone, near Aylesbury	Aptian Sands, white, false-bedded and iron-stained. 1912.

7648	(2) Windmill Pit, Stone, near Aylesbury	Aptian Sands, white, false-bedded and iron-stained. 1912.
7649	(3) Windmill Pit, Stone, near Aylesbury	Aptian Sands, white, false-bedded and iron-stained. 1912.
7650	(4) Windmill Pit, Stone, near Aylesbury	Aptian Sands, white, false-bedded and iron-stained. 1912.
7651	(5) Windmill Pit, Stone, near Aylesbury	False-bedded white sand and overlying clay of Aptian Age. 1912.

CORNWALL.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7652	(1) Tregithey	Spring thrown out at junction of hornblende schist and Veryan Beds.
7653	(2) Loe Bar	Shingle beach converting estuary into freshwater lake. 1913.
7654	(3) Loe Bar	Shingle beach converting estuary into freshwater lake. 1913.
7655	(4) Loe Bar	Shingle beach converting estuary into freshwater lake. 1913.
7656	(5) Land's End	Well-jointed granite cliffs.
7657	(6) Coverack	Black dyke cutting serpentine. 1913.
7658	(7) Coverack	Stack of serpentine. 1913.
7659	(8) Kennack	Dyke cutting serpentine.
7660	(9) Gunwalloe	Folded Veryan Series. 1913.
7661	(10) Gunwalloe	Disturbed Veryan Series. 1913.
7662	(11) Mullion Island . . .	1913.
7663	(12) Porthleven . . .	Giant's Rock, erratic of microcline gneiss. 1913.
7664	(13) Baulk Head, Lizard . .	Imperfect cleavage in Menaccan Series (L. Dev.). 1913.

DERBY.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7665	(1) River Bradford, near Youlgreave	Carboniferous Limestone cliff. 1914.
7666	(2) Tideswell Dale . . .	Dale scenery. 1914.
7667	(3) Tideswell Dale . . .	Typical dale scenery. 1914.
7668	(4) Tideswell Dale . . .	Typical dale scenery. 1914.
7669	(5) Tideswell Dale . . .	Spheroidal weathering of basalt. 1914.
7670	(6) Ravenstor, Miller's Dale .	Carboniferous Limestone (D_1) with toadstone at base of cliff. 1914.
7671	(7) Via Gellia	Spheroidal lower lava overlain by limestone. 1914.
7672	(8) Tideswell Dale . . .	Clay rendered columnar by dolerite sill. 1914.
7673	(9) Tideswell Dale . . .	Clay rendered columnar by dolerite sill. 1914.
7674	(10) Crich Hill—Hilt's Quarry .	D_2 Limestone. 1914.
7675	(11) 'Old Quarry,' Crich . .	Upper cherty part of D_2. 1914.
7676	(12) Matlock Bath . . .	Tufa. 1914.
7677	(13) Matlock Bath . . .	Tufa. 1914.
7678	(14) Matlock Bath . . .	Tufa. 1914.
7679	(15) Matlock Bath . . .	Tufa. 1914.
7680	(16) Ible Quarry, off Via Gellia .	Irregular jointing in dolerite. 1914.
7681	(17) 'Pig of Lead' Quarry, Via Gellia	Spheroidal weathering of lower lava. 1914.
7682	(18) Ible, Wirksworth . .	Sandy concretion (scrablag). 1914.
7683	(19) Ible, Wirksworth . .	Vein of chrysotile in dolerite. 1914.
7684	(20) Winster	Chert beds. 1914.

7685	(21) Bullsbridge, Ambergate .	Lower Coal Measure shale resting on marine band above Alton seam. 1914.
7686	(22) Bullsbridge, Ambergate .	Alton coal seam. 1914.
7687	(23) Cromford Black Rocks .	Millstone Grit crag. 1914.
7688	(24) Alport, Rowsley . . .	Ice-scratched boulder. 1914.

DEVONSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7689	Charton Bay, near Lyme Regis .	Grey marls of Keuper. 1914.
7690	Charton Bay, near Lyme Regis .	Grey marls of Keuper. 1914.
7691	Charton Bay, near Lyme Regis .	Grey marls of Keuper. 1914.
7692	(1) Chapel Rock, Pinhay Cliff .	Foundered mass of Chalk (H. planus and M. cor-testudinarium zones). 1914.
7693	(2) Axmouth or Dowlands landslip	General view looking E. 1914.
7694	(3) Axmouth or Dowlands landslip	General view looking E. 1914.
7695	(4) Axmouth or Dowlands landslip	General view looking E. 1914.
7696	(5) Axmouth or Dowlands landslip	General view looking E. 1914.
7697	(6) Axmouth or Dowlands landslip	General view looking E. 1914.
7698	(7) Axmouth or Dowlands landslip	General view looking W. 1914.
7699	(8) Axmouth or Dowlands landslip	Foundered mass of cliff. 1914.
7700	(9) Axmouth or Dowlands landslip	Foundered mass of cliff. 1914.
7701	(10) Axmouth or Dowlands landslip	Large slipped mass of Chalk. 1914.
7702	(11) Axmouth or Dowlands landslip	Shows pinnacles of slipped Chalk. 1914.
7703	(12) Axmouth or Dowlands landslip	Shows pinnacles of slipped Chalk. 1914.
7704	(13) Axmouth or Dowlands landslip	Shows pinnacles of slipped Chalk. 1914.
7705	(14) Axmouth or Dowlands landslip	Chasm between foundered mass and rock *in situ*. 1914.
7706	(15) Under Hooken and Hooken Cliff	Chalk and Upper Greensand section. 1914.
7707	(16) Beer Quarry . . .	Chalk—T. gracilis and R. cuvieri zones. 1914.
7708	(17) Beer Cliffs	Chalk section. 1914.

Photographed by L. G. ANNISS, B.Sc., 16 *Crownhill Park, Torquay.* $2\frac{1}{2}\times4\frac{1}{2}$.

7709	(1) Waterside Cove, Torbay .	Permian breccia unconformable on Staddon Grits. 1927.
7710	(2) Saltern Cove, Torquay . .	View looking S. 1927.
7711	(3) Saltern Cove, Torquay . .	View looking N. 1927.
7712	(4) Southern Horn, S. of Saltern Cove, Torquay	Shattered Devonian Limestone overthrust on dolerite. 1927.
7713	(5) Cove between Saltern Cove and Broadsands, Torbay	Faulted junction between Permian and Upper Devonian. 1927.
7714	(6) Saltern Cove, Torquay . .	Showing Sugarloaf Hill. 1927.

DORSET.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7715	(1) Ballard Cliffs, near Swanage .	Chalk sea-stacks. 1910.
7716	(2) Ballard Cliffs, near Swanage, from N.	Chalk sea-stacks. 1910.
7717	(3) Ballard Cliffs, near Swanage, from S.	Chalk sea-stacks. 1910.
7718	(4) Handfast Point, N. of Swanage	Erosion of Chalk. 1910.
7719	(5) Handfast Point, N. of Swanage, from N.	Stage in isolation of Chalk promontory. 1910.
7720	(6) Handfast Point, N. of Swanage	Erosion of Chalk. 1910.

7721	(7) E. end of Chalk ridge of Isle of Purbeck	Chalk cliffs and sea-stacks. 1910.
7722	(8) E. end of Chalk ridge of Isle of Purbeck	Chalk cliffs and sea-stacks. 1910.
7723	(9) Looking N. from Durlston Head	Differential erosion, hard bands forming promontories. 1910.
7724	(10) Peveril Point, Swanage .	Hard band in Up. Purbeck, forming point. 1910.
7725	(11) Near Peveril Point . .	Purbeck section. 1910.
7726	(12) Durlston Bay . . .	Purbeck section. 1910.
7727	(13) Durlston Bay . . .	Chert in Middle Purbeck. 1910.
7728	(14) Durlston Head . . .	Portland Stone capped by Purbeck. 1910.
7729	(15) Durlston Head and cliffs to the W.	Portland Stone capped by Purbeck. 1910.
7730	(16a) Durlston Head and cliffs to the W.	Chert beds (L. Portland Stone) conspicuous in the foreground. 1910.
7731	(16b) Near Tilly Whim, Swanage.	Formation of caves in Portland Stone. 1910.
7732	(17) Tilly Whim, Swanage . .	Portland section, showing openings of quarries (so-called caves) in the freestone beds. 1910.
7733	(18) Tilly Whim, Swanage . .	Chert beds (L. Portland Stone) and freestone beds (Up. Portland Stone) with 'cave' above. 1910.
7734	(19) Tilly Whim, Swanage . .	Quarry (so-called cave) in Upper (freestone beds) of Portland Stone. 1910.
7735	(20) Tilly Whim, Swanage . .	Portland Stone—sea-caves and fallen blocks. 1910.
7736	(21) Tilly Whim, Swanage . .	Portland Stone—sea-caves and fallen blocks. 1910.
7737	(22) Tilly Whim, Swanage . .	Undercutting of Portland Stone. 1910.
7738	(23) Dancing ledge E. of Seacombe	Up. Portland freestones undercut by the sea and overlain by Purbeck. 1910.
7739	(25) Hounstout Cliff . . .	Portlandian section. 1910.
7740	(26) Chapman's Pool and Hounstout Cliff	Kimmeridge and Portland section. 1910.
7741	(27) Chapman's Pool and Hounstout Cliff	Kimmeridge and Portland section. 1910.
7742	(28) Dungy Head and Man-of-War Cove, Lulworth	Inverted chalk in the foreground. 1910.
7743	(29) Man-of-War Cove, near Lulworth	The Man-of-War rock is vertical Portland, cliffs on the left inverted chalk. 1910.
7744	(30) Durdle Door promontory from E.	Section Portland to Wealden. 1910.
7745	(31) Durdle Door, near Lulworth, north face	N. face is formed of the 'Soft Cap' with 'trees.' 1910.
7746	(32) Durdle Door, near Lulworth.	The 'Door' is formed of the caps and top of the Portlands. 1910.
7747	(33) Durdle Door promontory, from W.	Section top of Portland to Wealden. 1910.
7748	(34) Durdle Door Cove . .	Sea-caves along thrust-plane traversing Chalk. 1910.
7749	(35) Durdle Door Cove . .	Sea-cave along thrust-plane traversing Chalk. 1910.
7750	(36) Durdle Door Cove . .	Sea-caves along thrust-plane traversing Chalk. 1910.
7751	(37) Coast W. of Durdle Door .	Chalk cliffs, thrust-plane in foreground. 1910.
7752	(38) Silton, N.W. of Gillingham .	Corallian section. 1916.
7753	(39) Gillingham . . .	Septaria from Kimmeridge Clay. 1916.
7754	(40) Gillingham . . .	Septaria from Kimmeridge Clay. 1916.
7755	(41) Gillingham . . .	Selenite crystals from Kimmeridge Clay. 1916.

Published by H. J. CHAFFEY, *W. Lulworth.* Postcard.

7756	Worberrow Bay and Mewp Rocks.	Purbeck section in foreground.
7757	Fossil Forest, W. Lulworth .	Section showing top of Portland, caps and Dirt Bed.
7758	'Fossil Forest,' W. Lulworth .	'Burr' or tufaceous deposit around tree-stump.
7759	Stair Cove, Lulworth . . .	Portland 'screen' and folded Purbecks.
7760	Durdle Door, Lulworth . .	Erosion features.

Photographed by SEWARD. Postcard.

7761	Man-of-War Cove, Lulworth .	Coast erosion features.

Photographed by the SURREY FLYING SERVICE, *Croydon.* Postcard.

7762	Lulworth Cove from the air. .	Contrast the extent of the erosion of Lulworth Cove with that of Stair Cove.
7763	W. Lulworth from the air . .	Shows section Portland Stone to Chalk.

Photographed by J. F. JACKSON, F.G.S., 4 *Elm Grove Estate, Newport, I.W.* 1/4.

7764	(38) Chapman's Pool, looking up Renscombe Valley	Up. Kimmeridge Clay capped by Portland on left. 1928.
7765	(39) Egmont Point from E. .	Kimmeridge Clay cliffs. 1928.
7766	(40) Chapman's Pool, about 5 m. S.W. of Swanage	Ammonites *in situ* in Kimmeridge Clay. 1928.
7767	(42) Winspit Quarry, about 4 m. S.W. of Swanage	Portland Stone capped by Purbeck. 1928.
7768	(43) W. side of Dungy Head, Lulworth	Chert beds of Portland Stone. 1928.
7769	(44) Durlston Head, Swanage .	Disturbed Lower Purbecks. 1928.
7770	(45) Durlston Head, Swanage .	Puckered L. Purbeck Limestone. 1928.
7771	(46) Durlston Head, Swanage .	Puckered L. Purbeck Limestone. 1928.
7772	(47) Durlston Head, Swanage .	'Broken Beds' on 'Hard Cap.' 1928.
7773	(48) Durlston Bay, Swanage .	Junction of Middle and Lower Purbeck. 1928.
7774	(49) Durlston Bay, Swanage .	Weathered surface of 'Flint Bed.' 1928.
7775	(50) Durlston Bay, Swanage .	Weathered surface of Cinder Bed. 1928.
7776	(51) Durlston Bay, Swanage .	Middle Purbeck section. 1928.
7777	(52) Durlston Bay, Swanage .	Weathered surface of Middle Purbeck (*Corbula* bed). 1928.
7778	(53) Peveril Point, Swanage .	Upper Purbeck Limestones and Shales. 1928.
7779	(54) Peveril Point, Swanage .	Effects of marine erosion. 1928.
7780	(55) Peveril Point, Swanage .	Folded Upper Purbeck Beds. 1928.
7781	(56) Entrance to Lulworth Cove, from top of cliffs to E.	Marine erosion of highly inclined beds. 1928.
7782	(57) Entrance to Lulworth Cove, seen from E.	Portland and Purbeck section. 1928.
7783	(58) E. side of Lulworth Cove .	Section Lower and Middle Purbecks. 1928.
7784	(59) Fossil Forest, Lulworth .	Section Upper Portland and Purbeck Rocks. 1928.
7785	(60) Fossil Forest, Lulworth .	'Burr' of tufa surrounding tree-stumps. 1928.
7786	(61) Fossil Forest, Lulworth .	Group of 'Burrs.' 1928.
7787	(62) Fossil Forest, Lulworth .	Detail of 'Dirt Bed.' 1928.
7788	(63) Durdle Door, Lulworth .	Natural arch in vertical Portlands and L. Purbecks. 1928.
7789	(64) Durdle Door, Lulworth .	Natural arch in vertical Portlands and L. Purbecks. 1928.

7790	(65) Man-of-War Cove, Lulworth, looking E.	Effects of marine erosion. 1928.
7791	(66) Durdle Cove, Lulworth .	Cliffs of highly disturbed chalk. 1928.
7792	(67) Coast from Dungy Head to White Nothe	Effects of marine erosion. 1928.
7793	(68) Durdle Cove, Lulworth .	Junction Cenomanian and Selbornian. 1928.

Photographed by S. H. Reynolds, M.A., Sc.D., *The University, Bristol.* 1/4.

7794	(28.1) Burton Bradstock . .	Cliff of Bridport Sand. 1928.
7795	(28.3) Burton Bradstock . .	Rock-fall of Bridport Sand. 1928.
7796	(28.4) Burton Bradstock . .	Concretions, Bridport Sand. 1928.
7797	(28.5) E. Cliff, Bridport . .	Bridport Sand. 1928.
7798	(28.6) E. Cliff, Bridport . .	Bridport Sand. 1928.
7799	(28.9) Charmouth . . .	Contorted band in Lias. 1928.
7800	(28.11) Down Cliff, Seatown .	Middle and Upper Lias section. 1928.

Durham.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

7801	Fulwell	Magnesian Limestone concretions. 1912.
7802	Fulwell	Magnesian Limestone concretions. 1912.

Essex.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

7803	One-tree Hill Pit, Laindon Hills .	Bagshot Sands. 1907.
7804	Railway Cutting, Saffron Walden.	Glacial clays and gravels overlying Chalk. 1911.

Gloucestershire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

7805	Aust Cliff	Southern faults. 1919.
7806	Aust Cliff	Second fault. 1919.
7807	Aust Cliff	Third fault. 1919.
7808	Avon Section	Carboniferous Limestone section C_1–D. 1919.
7809	Avon Section, Gully Quarry. .	*Caninia* dolomite (C_2) on *Caninia* oolite (C_1). 1919.
7810	Avon Section. Sea Walls . .	Level surface, planing probably completed by Liassic sea. 1919.
7811	Avon Section, S. end, Great Quarry	S_2 section. 1919.
7812	Observatory Hill and Suspension Bridge, looking N.	S_2 section repeated by fault. 1919.
7813	Section near Suspension Bridge, Clifton	S_2 and D section repeated by fault. 1919.

Hampshire.—*Photographed by the late* T. W. Reader *and presented by* F. W. Reader. 1/4.

7814	Nately Scures, near Hook . .	Base of London Clay on Reading Beds. 1911.
7815	Nately Scures, near Hook . .	Sandstone bed in Reading series. 1911.
7816	Wilkinson's Gravel Pit, Farnham.	Upper and lower gravels separated by sand. 1913.

HAMPSHIRE (ISLE OF WIGHT).—*Photographed by* J. F. JACKSON, F.G.S., 4 *Elm Grove Estate, Newport, I.W., and presented by* Miss C. MOREY. 1/4.

7817	(216) Cliff at Tie Pits N.W. of Atherfield Point	Junction of Wealden shale and Atherfield Clay. 1927.
7818	(217) Atherfield Point . .	Natural section of an aged example of *Exogyra sinuata*. 1927.
7819	(218) Fishing Cove, Atherfield cliffs	Weathered fossiliferous nodule from 'Crackers' bed of Ferruginous Sand. 1927.
7820	(219) Ladder Chine, Chale Bay . .	Erosion of cliffs of soft sandstone by wind and rain. 1927.
7821	(220) Hamstead Duver, Hamstead	Shingle spit protecting salt marsh. 1925.

HERTFORDSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7822	Ayot	Reading Sands disturbed probably by glacial action. 1910.
7823	Tyttenhanger Pit, St. Albans .	Chalky Boulder Clay with associated sands and gravels.
7824	Sandy Lodge, Northwood . .	Reading Sand section. 1910.
7825	Sandy Lodge, Northwood . .	Reading Sands and pebble beds. 1910.

KENT.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7826	(1) Groombridge . . .	Weathering along joints in Wealden Sandstone. 1909.
7827	(2) Eridge Rocks . . .	Weathering along joints and bedding planes in Wealden sandstone. 1909.
7828	(3) Eridge Rocks . . .	Characteristic lane in Tunbridge Wells Sand. 1909.
7829	(4) Stoneham's Pit, North End, Crayford	River gravel of Middle Terrace. 1913.
7830	(5) Oldhaven Gap . . .	London Clay section.
7831	(6) Herne Bay	Selenite crystals from Oldhaven Beds. 1912.
7832	(7) Slade's Green . . .	Brick earth section. 1913.
7833	(8) Southend, near Beckenham .	Blackheath Beds. 1921.
7834	(9) Southend, near Beckenham .	Blackheath Beds with scattered lines of pebbles. 1921.
7835	(10) Stone Street, 3 m. E. of Sevenoaks	Current-bedded Folkestone Sand. 1915.
7836	(11) Stone Street, 3 m. E. of Sevenoaks	Current-bedded Folkestone Sand. 1915.
7837	(12) Stone Street, 3 m. E. of Sevenoaks	Current-bedded Folkestone Sand. 1915.
7838	(13) Stone Street, 3 m. E. of Sevenoaks	Current-bedded Folkestone Sand. 1915.
7839	(14) Greenhithe . . .	Shattered flints recemented by secondary silica. 1914.
7840	(15) Globe Pit, Greenhithe . .	Gravel on Thanet Sands on Chalk. 1912.
7841	(16) Globe Pit, Greenhithe . .	Chalk overlain by gravel-capped Thanet Sand. 1912.
7842	(17) New Globe Pit, Greenhithe .	Drift on Thanet Sand. 1912.
7843	(18) Tollgate Pit, Greenhithe .	Gravel on Thanet Sand on Chalk. 1914.
7844	(19) Howe Hill gravel pit, Greenhithe	False-bedded gravel. 1914.
7845	(20) Stone Court Gravel Pit, Cotton Lane, Greenhithe	Dartford Heath Gravel, on Thanet Sand, on Chalk. 1914.

7846	(21) Stone Court Gravel Pit, Cotton Lane, Greenhithe	Dartford Heath Gravel on Thanet Sand. 1914.
7847	(22) Stone Court Gravel Pit, Cotton Lane, Greenhithe	Gravel on Chalk with pockets of Thanet Sand. 1914.
7848	(22x) Stone Court, Gravel Pit, Cotton Lane, Greenhithe	Method of working. 1914.
7849	(23) Howe Hill Gravel Pit, Greenhithe	Gravel section on Chalk. 1914.
7850	(24) Howe Hill Gravel Pit, Greenhithe	Gravel section on Chalk. 1914.
7851	(25) Castle Cross Gravel Pit, Greenhithe	Dartford Heath Gravel on Chalk. 1914.
7852	(26) Martin's Pit, Horn's Cross, Greenhithe	Dartford Heath Gravel. 1914.

MIDDLESEX.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7853	Ponder's End	Low level gravels near station. 1909.

OXFORDSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7854	(1) Vicarage Quarry, Headington.	Corallian section. 1915.
7855	(2) Vicarage Quarry, Headington.	Corallian section. 1915.
7856	(3) Vicarage Quarry, Headington.	Upper Corallian section, Lower Calcareous Grit at base. 1915.
7857	(4) Vicarage Quarry, Headington.	Corallian section (detail). 1915.
7858	(5) Vicarage Quarry, Headington.	Upper Corallian section, Lower Calcareous Grit at base. 1915.
7859	(6) Windmill Road Quarry, Headington	Corallian section. 1915.
7860	(7) Windmill Road Quarry, Headington	Corallian section. 1915.
7861	(8) St. Ebba's Priory, Headington	Junction Kimmeridge Clay and Upper Corallian. 1915.
7862	(9) Shotover Brick Works . .	Kimmeridge Clay—*rotundum* to *virgatites* zones. 1915.
7863	(10) Shotover	General view of brickyard—Shotover Sand on Kimmeridge Clay. 1915.
7864	(11) Top of Shotover Hill . .	Shotover Sand (=Hastings Sand) on Portland Sand. 1915.
7865	(12) Top of Shotover Hill . .	Shotover Sand (=Hastings Sand) on Portland Sand. 1915.
7866	(13) Shotover	Shotover Ironsand on Upper Portland Sand. 1915.
7867	(14) Top of Shotover Hill . .	Shotover Sand (=Hastings Sand) on Portland Sand. 1915.
7868	(15) Shotover Brickyard . .	Doggers in Kimmeridge sand (*pectinatus* zone). 1915.
7869	(16) Shotover	Shotover Sand with doggers. 1915.
7870	(17) Shotover	Portlandian and Upper Kimmeridge Clay section. 1915.
7871	(18) Pishill, Hollandridge, near Henley	Double tabular flints in joint planes of chalk. 1915.

SHROPSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7872	Harley Hill, Wenlock Edge. .	Rubbly Wenlock Limestone.

SOMERSET.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7873	Snowden Hill Pit, Chard . .	Upper Greensand and Chloritic Marl. 1911.
7874	Woodspring Promontory, general view of N. coast	Shows raised beach platform in distance. 1919.
7875	Portishead	O.R.S. with cornstone masses seen on right. 1919.
7876	Greenham Quarry, Gamlins, near Nynehead	Culm Limestone. 1911.
7877	Nynehead, near Taunton . .	Road cutting in Keuper. 1911.
7878	Holywell Lake, near Nynehead .	Bunter Sandstone and Pebble beds. 1911.
7879	Hestercombe, near Taunton .	Morte Slates. 1911.
7880	Woodlands Quarry, Holford .	Hangman Grits. 1913.
7881	Hawkridge Common Quarry, Quantocks	Mid. Devonian Limestone. 1911.
7882	Aley Quarry, Adscombe . .	Fossiliferous Mid. Devonian Limestone. 1911.
7883	Dibble's Quarry, Quantock Lodge	Quarry in Schalstein. 1911.
7884	Dibble's Quarry, Quantock Lodge	Quarry in Schalstein. 1911.

Photographed by F. F. MISKIN, F.G.S., 46 *Windsor Road, Penarth, and presented by the* NATIONAL MUSEUM OF WALES *per* DR. F. J. NORTH. 1/4.

7885	(N.M.W. ¼) (4207) Steep Holm, Bristol Channel	Solution weathering in Carboniferous Limestone.
7886	(N.M.W. ¼) (4271) Flat Holm Island, Bristol Channel	Marine erosion of Carboniferous Limestone dipping seawards.
7887	(N.M.W. ¼) (4272) Flat Holm Island, Bristol Channel	Marine erosion of Carboniferous Limestone.
7888	(N.M.W. ¼) (4197) Flat Holm, Bristol Channel	Marine erosion along bedding plane of Carboniferous Limestone.
7889	(N.M.W. ¼) (4198) Flat Holm, Bristol Channel	Pebble beach.
7890	(N.M.W. ¼) (4201) Flat Holm, Bristol Channel	Marine erosion of Carboniferous Limestone along bedding planes.
7891	(N.M.W. ¼) (4202) Flat Holm, Bristol Channel	Marine erosion along bedding plane in Carboniferous Limestone.
7892	(N.M.W. ¼) (4200) Flat Holm, Bristol Channel	Relative efficiency of sub-aerial as compared with marine erosion.
7893	(N.M.W. ¼) (4203) Flat Holm, Bristol Channel	Carboniferous Limestone coast.
7894	(N.M.W. ¼) (4204) Flat Holm, Bristol Channel	Disturbed Carboniferous Limestone.

SURREY.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7895	(1) Netley Heath . . .	Pliocene? sand and gravelly clay with flints. 1914.
7896	(2) Netley Heath . . .	Pliocene? sand and gravelly clay with flints. 1914.

7897	(3) Netley Heath . . .	Pliocene? sand and gravelly clay with flints. 1914.
7898	(4) Netley Heath . . .	Pliocene? sand and gravelly clay. 1914.
7899	(5) Netley Heath . . .	Pliocene? sand and clay with flints. 1914.
7900	(6) Netley Heath . . .	Detail of Pliocene? pebbly gravel. 1914.
7901	(7) Netley Heath . . .	Ironstone concretions (boxstones) from ?Pliocene. 1914.
7902	(8) Oxted	Cherty Hythe Beds. 1915.
7903	(9) Oxted	Cherty Hythe Beds. 1915.
7904	(10) Oxted	Folkestone Sands. 1915.
7905	(11) Oxted	Folkestone Sands. 1915.
7906	(12) Wray Common, Reigate .	Folkestone Beds capped by base of Gault. 1910.
7907	(13) Rookery section, Wotton .	Faulted Carstone section. 1914.
7908	(14) Wotton, near Dorking .	Section of Carstone (Lower Greensand). 1914.
7909	(15) Rookery Section, Wotton .	Detail of Carstone. 1914.
7910	(16) Wotton	Bargate Stone in road section. 1914.
7911	(17) Albury Down Chalk Pit .	Junction of Middle and Lower Chalk. 1912.
7912	(18) Albury Lane, S. of Newlands Corner	Current-bedded Lower Greensand. 1912.
7913	(19) Albury Lane, S. of Newlands Corner	Current-bedded Lower Greensand. 1912.
7914	(20) Albury Lane, S. of Newlands Corner	Current-bedded Lower Greensand. 1912.
7915	(21) Coombs Pit, W. Horsley .	Upper Chalk, zone of *M. cor-anguinum*. 1914.
7916	(22) Coombs Pit, W. Horsley .	Upper Chalk, zone of *M. cor-anguinum*. 1914.
7917	(23) Newlands Corner . .	View looking south over Weald. 1912.
7918	(24) Newlands Corner . .	Gravel Pit. 1912.
7919	(25) St. Catherine's Hill, Guildford	Spring in Lower Greensand. 1911.
7920	(26) Chalk Pit, opposite Clandon Park, between Leatherhead and Guildford	Chalk, *Marsupites* zone.
7921	(27) Littleton Farm, near Guildford	Bargate Stone. 1911.
7922	(28) Littleton, near Guildford .	Bargate Stone showing dip. 1911.
7923	(29) Marden Park, N. Downs .	Detail Blackheath pebble beds. 1914.
7924	(30) Pitch Hill	Lower Ferruginous Sands overlain by chert beds. 1914.
7925	(31) Pitch Hill	Lower Ferruginous Sands overlain by chert beds. 1914.
7926	(32) Frith Hill, Godalming . .	Bargate Stone and current-bedded sand. 1911.
7927	(33) Frith Hill, Godalming . .	Bargate Stone and current-bedded sand. 1911.
7928	(34) Frith Hill, Godalming . .	Current bedding in Bargate Stone. 1911.
7929	(35) Northbrook Place, near Godalming	Lenticular structure of Bargate Stone.
7930	(36) Wilkinson's Gravel Pit, Farnham	Upper and lower gravels separated by sand. 1913.
7931	(37) Paine's Field, Shortheath, Farnham	Hillwash on brickearth on gravel. 1913.
7932	(38) Paine's Field, Shortheath, Farnham	Gravel surmounted by brickearth and hillwash (Terrace B). 1913.
7933	(39) Brook Street Pit, Hindhead.	Lower Ferruginous Sands on passage loams to Atherfield Clay. 1914.
7934	(40) Beddington . . .	Thanet Sand section.
7935	(41) Oxshott Heath . . .	Bagshot Sand with concretions and seams of pipeclay. 1914.

SUSSEX.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7936 Ecclesbourne, near Hastings . Wealden section. 1907.
7937 Hastings . . . . . . Shale with *Cypridea valdensis*. 1907.
7938 Hastings . . . . . . Rock-a-more dew pond. 1907.
7939 Hastings . . . . . . Rock-a-more dew pond. 1907.

WESTMORLAND.—*Photographed by* F. F. MISKIN, F.G.S., 46 *Windsor Road, Penarth, and presented by the* NATIONAL MUSEUM OF WALES *per* Dr. F. J. NORTH. 1/4.

(N.M.W. ¼)
7940 (4235) Rydal Water . . . Rydal Water

(N.M.W. ¼)
7941 (4236) Stream connecting Rydal and Windermere

(N.M.W. ¼)
7942 (4239) Beetham, near Kendal . Joints in Carboniferous Limestone widened by solution.

(N.M.W. ¼)
7943 (4240) Fairy Steps, near Beetham Enlarged joints in Carboniferous Limestone.

WILTSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7944 Ladydown, near Tisbury . . Purbeck section. 1911.
7945 Ladydown, near Tisbury . . Solution channels in Mid. Purbeck beds. 1911.
7946 Maiden Bradley Quarry . . 'Cornstone' concretions from base of Cenomanian. 1916.
7947 Maiden Bradley Quarry . . 'Cornstone' concretions from base of Cenomanian. 1916.
7948 Crockerton, near Maiden Bradley. Septaria from Gault. 1916.

YORKSHIRE.—*Photographed by the late* T. W. READER *and presented by* F. W. READER. 1/4.

7949 (1) Giggleswick Scars, Settle . Fault scarp of Carboniferous Limestone. 1910.
7950 (2) Giggleswick Scars, Settle . Fault scarp of Carboniferous Limestone. 1910.
7951 (3) Arco Wood, near Horton-in-Ribblesdale Carboniferous Limestone on Horton Flags (Silurian). 1910.
7952 (4) Arco Wood, near Horton-in-Ribblesdale Carboniferous Limestone on Horton Flags (Silurian). 1910.
7953 (5) Thirl or Hull Pot, near Horton-in-Ribblesdale In D_2 limestone. 1910.
7954 (6) Thirl or Hull Pot, Horton-in-Ribblesdale Inflowing stream. 1910.
7955 (7) Cam Beck, near Gearstones Inn, Ribblehead Characteristic beck in Carboniferous Limestone. 1910.
7956 (8) Cam Beck, near Gearstones Inn, Ribblehead Characteristic beck in Carboniferous Limestone. 1910.
7957 (9) Cam Beck, near Gearstones Inn, Ribblehead Characteristic beck in Carboniferous Limestone. 1910.
7958 (10) Cam Beck, near Gearstones Inn, Ribblehead Characteristic beck in Carboniferous Limestone. 1910.
7959 (11) Cam Beck, near Gearstones Inn, Ribblehead Characteristic beck in Carboniferous Limestone. 1910.

WALES.

BRECON.—*Photographed by* W. E. HOWARTH, F.G.S., *National Museum of Wales, and presented by the* NATIONAL MUSEUM OF WALES *per* Dr. F. J. NORTH. 1/4.

7960	(N.M.W. $\frac{1}{4}$) (4348) Little Neath, looking N. towards Nant-y-moch	Rejuvenated stream in plateau country formed of O.R.S. 1926.
7961	(N.M.W. $\frac{1}{4}$) (4349) W. flanks of Fan Nedd seen from Nant-y-moch	Rejuvenation phenomena, stream dissection in Old Red plateau country. 1926.
7962	(N.M.W. $\frac{1}{4}$) (4350) Headwaters of Nant-y-moch	Rejuvenation phenomena in Old Red plateau country. 1926.
7963	(N.M.W. $\frac{1}{4}$) (4351) Nant-y-moch confluence with Little Neath	Hanging valley in Old Red plateau country. 1926.

Photographed by F. F. MISKIN, F.G.S., 46 *Windsor Road, Penarth, and presented by the* NATIONAL MUSEUM OF WALES *per* Dr. F. J. NORTH. 1/4.

7964	(N.M.W. $\frac{1}{4}$) (4266) R. Usk, Penmyarth, W. of Crickhowell	

CARDIGAN.—*Photographed by* A. J. LEWIS, *The Mart, Aberystwyth.* E.

7965	(1) N. end of Marine Terrace, Aberystwyth	Effects of storm of Oct. 28th, 1927. 1927.
7966	(2) N. end of Marine Terrace, Aberystwyth	Effects of storm of Oct. 28th, 1927. 1927.
7967	(3) N. end of Marine Terrace, Aberystwyth	Effects of storm of Oct. 28th, 1927. 1927.
7968	(4) N. end of Marine Terrace, Aberystwyth	Effects of storm of Oct. 28th, 1927. 1927.
7969	(5) N. end of Marine Terrace, Aberystwyth	Effects of storm of Oct. 28th, 1927. 1927.
7970	(6) N. end of Marine Terrace, Aberystwyth	Effects of storm of Oct. 28th, 1927. 1927.
7971	(7) N. end of Marine Terrace, Aberystwyth	Effects of storm of Oct. 28th, 1927. 1927.
7972	(8) S. Marine Terrace, Aberystwyth	Effect of storm of Oct. 28th, 1927. 1927.
7973	(9) Borth, N. of Aberystwyth .	Effect of storm of Oct. 28th, 1927. 1927.
7974	(10) Borth, N. of Aberystwyth .	Effect of storm of Oct. 28th, 1927.

Photographed by J. CHALLINOR, M.A., F.G.S., *University College of Wales, Aberystwyth.* $4\frac{1}{2} \times 5$ *and* Postcard.

7975	(11) N. end of Marine Terrace, Aberystwyth	Effect of storm of Oct. 28th, 1927. 1927. $4\frac{1}{2} \times 5$.
7976	(12) N. end of Marine Terrace, Aberystwyth	Effects of storm of Oct. 28th, 1927. 1927. $4\frac{1}{2} \times 5$.
7977	(13) N. end of Marine Terrace, Aberystwyth	Effect of storm of Oct. 28th, 1927. 1927. Postcard.
7978	(14) N. end of Marine Terrace, Aberystwyth	Effect of storm of Oct. 28th, 1927. 1927. Postcard.

CARNARVON.—*Photographed by* P. B. ROBERTS, B.Sc., B.M./F.K.R.S., *W.C.* 1. 1/2.

7979	(13) Tryfan	Nodular rhyolite in the foreground. 1924.
7980	(14) Nant Ffrancon and the Glyders	Hanging valley. 1924.
7981	(15) Tryfan	Spur between two hanging valleys. 1925.
7982	(16) Tryfan	Frost-shattered summit of mountain. 1924.

Photographed by F. F. MISKIN, F.G.S., 46 *Windsor Road, Penarth, and presented by the* NATIONAL MUSEUM OF WALES *per* Dr. F. J. NORTH. 1/4.

7983	(N.M.W. ¼) (4245) Upper Swallow Falls, Bettws-y-coed	
7984	(N.M.W. ¼) Middle Swallow Falls, Bettws-y-coed	

DENBIGH.—*Photographed by* F. F. MISKIN, F.G.S., 46 *Windsor Road, Penarth, and presented by the* NATIONAL MUSEUM OF WALES *per* Dr. F. J. NORTH. 1/4.

7985	(N.M.W. ¼) (4232) Trevor Rocks, near Llangollen	Current-bedded Millstone Grit.
7986	(N.M.W. ¼) (4255) World's End . . .	Valley along fault in Carboniferous Limestone.
7987	(N.M.W. ¼) (4264) Eglwyseg, near Llangollen.	Carboniferous Limestone escarpment.

GLAMORGAN.—*Photographed by* F. F. MISKIN, F.G.S., 46 *Windsor Road, Penarth, and presented by the* NATIONAL MUSEUM OF WALES *per* Dr. F. J. NORTH. 1/4.

7988	(N.M.W. ¼) (4133) Bendrick Rock, 1 m. W. of Barry Island	Trias unconformable on Carboniferous Limestone.
7989	(N.M.W. ¼) (4175) Barry Island, Little Island	Trias unconformable on Carboniferous Limestone.
7990	(N.M.W. ¼) (4176) Barry Island, Little Island	Red Keuper marls with gypsum.
7991	(N.M.W. ¼) (4166) W. side of Barry Harbour.	Disturbed Lias Section.
7992	(N.M.W. ¼) (4163) St. Mary's Well Bay, 5 m. S. of Cardiff	Overthrust in 'Sully beds.'
7993	(N.M.W. ¼) (4142) St. Mary's Well Bay, 5 m. S. of Cardiff	Foreshore section of Lower Lias.
7994	(N.M.W. ¼) (4165) Seven Sisters Cliff, 1 m. S. of Penarth	Keuper marl with Gypsum.

	(N.M.W. ¼)	
7995	(4141) Seven Sisters Cliff, 1 m. S. of Penarth	Succession Lower Lias to 'Sully beds.'
	(N.M.W. ¼)	
7996	(4181) Seven Sisters Cliff, 1 m. S. of Penarth	Succession Lower Lias to 'Sully beds.'
	(N.M.W. ¼)	
7997	(4190) Penarth Head . .	Trough faults in Tea Green and Red Marls.
	(N.M.W. ¼)	
7998	(4159) Penarth Head, 3 m. S. of Cardiff	Section Lower Lias to Keuper.
	(N.M.W. ¼)	
7999	(4191) Penarth Head, near Cardiff	Conglomerate band below *Ostrea bristovi* bed at top of Tea Green marl.
	(N.M.W. ¼)	
8000	(4182) Lavernock, 5 m. S. of Cardiff	Tea-Green marl section.
	(N.M.W. ¼)	
8001	(4183) Lavernock Point, 5 m. S. of Cardiff	Tea-Green marl section.
	(N.M.W. ¼)	
8002	(4180) Lavernock Point, 5 m. S. of Cardiff	Black shales of Lower Rhaetic on 'Sully beds.'
	(N.M.W. ¼)	
8003	(4184) Lavernock Farm Cliff, 5 m. S. of Cardiff	Section of 'Sully beds.'
	(N.M.W. ¼)	
8004	(4156) Cliff below Lavernock Farm, 5 m. S.W. of Cardiff	White Lias on sun-cracked Upper Rhaetic.
	(N.M.W. ¼)	
8005	(4185) Lavernock, 5 m. S. of Cardiff	Rippled and sun-cracked slabs of Rhaetic sandstone.
	(N.M.W. ¼)	
8006	(4187) Lavernock, 5 m. S. of Cardiff	Section of lower part of Lias.
	(N.M.W. ¼)	
8007	(4153) Lavernock Point, 5 m. S. of Cardiff	Lower Lias limestones and shales.
	(N.M.W. ¼)	
8008	(4178) Lavernock, 5 m. S. of Cardiff	Black shale of Rhaetic resting on Grey or Tea Green marl.
	(N.M.W. ¼)	
8009	(4171) Lavernock Point, 5 m. S. of Cardiff	Lower Lias section, top of Rhaetic at base of cliff.
	(N.M.W. ¼)	
8010	(4150) Lavernock Point, 5 m. S. of Cardiff	Bedding and jointing in Lower Lias shales and limestones.
	(N.M.W. ¼)	
8011	(4149) Foreshore, Lavernock Point, 5 m. S. of Cardiff	Syncline in Lower Lias.
	(N.M.W. ¼)	
8012	(4172) Lavernock, 5 m. S. of Cardiff	Trough of syncline in Lower Lias.
	(N.M.W. ¼)	
8013	(4143) Lavernock, 5 m. S. of Cardiff	Jointed bedding plane of Lower Lias.

8014	(N.M.W. $\frac{1}{4}$) (4208) Lavernock, 5 m. S. of Cardiff	Foreshore of Lias limestone.
8015	(N.M.W. $\frac{1}{4}$) (4140) Lavernock, 5 m. S. of Cardiff	Bedding plane of Lower Lias limestone.
8016	(N.M.W. $\frac{1}{4}$) (4279) Lavernock . . .	Marine erosion of White Lias and undercutting of cliff.
8017	(N.M.W. $\frac{1}{4}$) (4135) Railway cutting, $\frac{3}{4}$ m. W. of Lavernock Station	Carboniferous Limestone section.
8018	(N.M.W. $\frac{1}{4}$) (4167) Sully Island, 6 m. S.S.W. of Cardiff	Trias unconformable on Carboniferous Limestone.
8019	(N.M.W. $\frac{1}{4}$) (4134) Headland, Sully Island, 5 m. S.S.W. of Cardiff	Trias unconformable on Carboniferous Limestone.
8020	(N.M.W. $\frac{1}{4}$) (4152) Sully Island, 5 m. S.S.W. of Cardiff	Undercutting of horizontally bedded Trias.
8021	(N.M.W. $\frac{1}{4}$) (4136) Sully Island (south side), 5 m. S.S.W. of Cardiff	Trias faulted against Carboniferous Limestone.
8022	(N.M.W. $\frac{1}{4}$) (4154) Swanbridge, near Sully Island, 5 m. S.S.W. of Cardiff	Fault in Trias.
8023	(N.M.W. $\frac{1}{4}$) (4177) Swanbridge, 5 m. S.S.W. of Cardiff	Step-faulting in Trias.
8024	(N.M.W. $\frac{1}{4}$) (4664) Rhoose	Lower Lias section.

PEMBROKE.—*Photographed by* F. F. MISKIN, F.G.S., 46 *Windsor Road, Penarth, and presented by the* NATIONAL MUSEUM OF WALES *per* Dr. F. J. NORTH. 1/4.

8025	(N.M.W. $\frac{1}{4}$) (4269) Tenby	Sharp anticline in Carboniferous Limestone.
8026	(N.M.W. $\frac{1}{4}$) (4270) Tenby	Thrust-planes traversing Carboniferous Limestone.
8027	(N.M.W. $\frac{1}{4}$) (4221) Caldy Island . . .	Sea-caves in vertical Carboniferous Limestone.
8028	(N.M.W. $\frac{1}{4}$) (4268) Caldy Island . . .	Marine erosion above present high-water mark.
8029	(N.M.W. $\frac{1}{4}$) (4220) Caldy Island . . .	Raised Beach on Carboniferous Limestone.
8030	(N.M.W. $\frac{1}{4}$) (4219) Caldy Island . . .	Vertical Old Red Sandstone.
8031	(N.M.W. $\frac{1}{4}$) (4222) Caldy Island . . .	Marine erosion of vertical strata.
8032	(N.M.W. $\frac{1}{4}$) (4225) Pwll, near Dinas Cross .	Natural Arch in Ordovician.
8033	(N.M.W. $\frac{1}{4}$) (4211) Newport Bay . . .	Sea-cave in contorted Ordovicians.

Scotland.

Argyll.—*Photographed by* S. H. Reynolds, M.A., Sc.D., *The University, Bristol.* 1/4.

8034	(48·27)	Inellan, Clyde shore	Limestone in Old Red Sandstone. 1927.
8035	(49·27)	Inellan, Clyde shore	Limestone bands in Old Red Sandstone. 1927.
8036	(50·27)	Inellan, Clyde shore	Breccia in Old Red Sandstone. 1927.
8037	(51·27)	Inellan, Clyde shore	Breccia in Old Red Sandstone. 1927.
8038	(53·27)	Inellan, Clyde shore	Dyke breaking across bedding of Old Red conglomerate. 1927.
8039	(54·27)	Inellan, Clyde shore	Current-bedded Old Red Sandstone. 1927.
8040	(56·27)	Inellan, Clyde shore	Limestone nodules in Old Red Sandstone. 1927.
8041	(71·27)	Seil Sound, near Oban	Raised Beach platform. 1927.
8042	(72·27)	Easdale, Oban	Scree of Old Red lava. 1927.
8043	(59·27)	North end of Kerrera, Oban	Rude columnar jointing in dolerite dyke. 1927.
8044	(60·27)	Near N. end of Kerrera, Oban	Unconformity, Old Red Sandstone on Easdale Slate. 1927.
8045	(61·27)	Kerrera, Oban	Unconformity, Old Red Sandstone on Easdale Slate. 1927.
8046	(63·27)	Gylen Castle, Kerrera, Oban	Castle stands on raised sea-cliff of Old Red conglomerate. 1927.
8047	(65·27)	Gylen Bay, Kerrera, Oban	Old Red conglomerate. 1927.
8048	(66·27)	Gylen Bay, Kerrera, Oban	Dyke in Old Red conglomerate. 1927.
8049	(67·27)	Gylen Bay, Kerrera, Oban	Sandstone in Old Red conglomerate. 1927.
8050	(79·27)	Mull, W. of Carsaig Bay	Basalt on Lias. 1927.
8051	(81·27)	Ross of Mull, S.W. coast	Granite rocks. 1927.
8052	(83·27)	W. end, Ross of Mull	Granite shore. 1927.
8053	(84·27)	Ross of Mull, W. end	Ravine due to erosion along dyke in granite. 1927.
8054	(85·27)	Mull, landing place, Fionphort	Highly jointed granite. 1927.
8055	(86·27)	Fionphort, Ross of Mull	Large split erratic. 1927.
8056	(87·27)	Fionphort, Ross of Mull	Large split erratic. 1927.
8057	(73·27)	Iona, near middle of west coast	Hummock of 'white rock.' 1927.
8058	(74·27)	N. end of Iona	Banded gneiss. 1927.
8059	(90·27)	Kentallen	Granite with inclusions. 1927.
8060	(91·27)	Kentallen	Pitted weathering of Kentallenite. 1927.

Ayr.—*Photographed by* S. H. Reynolds, M.A., Sc.D., *The University, Bristol.* 1/4.

8061	(24·27)	Craigmulloch, Loch Doon.	Inclusions in granite. 1927.
8062	(26·27)	½ m. S.S.E. of Craiglee, Loch Doon	Aplite veins in granite. 1927.
8063	(27·27)	W. of Loch Riecawr, Loch Doon	Tree-stump in peat. 1927.

Bute.—*Photographed by* S. H. Reynolds, M.A., Sc.D., *The University, Bristol.* 1/4.

8064	(39·27)	Keppel, Great Cumbrae, Lion Rock	Dolerite dyke. 1927.
8065	(41·27)	Keppel, Great Cumbrae, Lion Rock	Dolerite dyke. 1927.

8066	(40·27) Keppel, Great Cumbrae, Lion Rock	Dolerite dyke. 1927.
8067	(43·27) Deil's dyke, Keppel, Great Cumbrae	Dolerite dyke. 1927.
8068	(46·27) Keppel, Great Cumbrae .	Raised Beach platform. 1927.

INVERNESS.—*Photographed by* S. H. REYNOLDS, M.A., Sc.D., *The University, Bristol.* 1/4.

8069	(166·27) Cleadale, Eigg . .	Old sea cliff overlooking raised-beach platform. 1927.
8070	(136·27) Above Cleadale, Eigg .	Basalt cliff. 1927.
8071	(141·27) Eigg, cliffs of N.E. coast.	Basalt with columnar dolerite on sandstone. 1927.
8072	(143·27) Eigg, N.E. coast . .	Basalt cliff with rock-fall below. 1927.
8073	(144·27) Eigg, N.E. coast . .	Dyke cutting bedded basalts. 1927.
8074	(145·27) Eigg, N.E. coast . .	Basalt cliffs with dyke. 1927.
8075	(146·27) Eigg, E. coast . .	Basalt cliff with fallen masses. 1927.
8076	(149·27) Eigg, N. of Kildonan .	Basalt cliff with dolerite. 1927.
8077	(150·27) N.E. of Kildonan, Eigg .	Basalt cliffs. 1927.
8078	(99·27) Eigg	E. end of Sgurr from N.E. with dolerite terraces below. 1927.
8079	(101·27) Eigg, end of Sgurr from N.E.	Pitchstone ridge and plateau-basalt series below. 1927.
8080	(102·27) Eigg, top of Sgurr from E.	Pitchstone on inclined basalt. 1927.
8081	(105·27) Eigg, E. end of Sgurr from S.E.	Bedded basalts seen below pitchstone. 1927.
8082	(106·27) Eigg, part of S.E. face of the Sgurr	Columnar pitchstone with felsite sill. 1927.
8083	(109·27) Eigg, part of S.E. face of the Sgurr	Felsite sills in pitchstone. 1927.
8084	(110·27) Eigg, part of S.E. face of the Sgurr	Felsite sills in pitchstone. 1927.
8085	(111·27) Eigg, S. face of Sgurr .	Felsite sills in pitchstone. 1927.
8086	(117·27) Eigg, S. face of Sgurr .	Divergent pitchstone columns. 1927.
8087	(118·27) Eigg, top of Sgurr .	Columnar pitchstone. 1927.
8088	(120·27) Eigg, part of S. face of Sgurr	Radiating columns of pitchstone. 1927.
8089	(122·27) Eigg, part of precipice, S. side of Sgurr	Shows columnar jointing of pitchstone. 1927.
8090	(123·27) Sgurr of Eigg . .	Pitchstone columns, top of the ridge. 1927.
8091	(124·27) Eigg, top of Sgurr .	Pitchstone columns. 1927.
8092	(125·27) Eigg, top of Sgurr ridge.	Small loch in pitchstone. 1927.
8093	(126·27) Sgurr of Eigg . .	Small lochs on the ridge. 1927.
8094	(127·27) Eigg, W. part of Sgurr ridge	Small loch in pitchstone. 1927.
8095	(128·27) Eigg, top of Sgurr ridge.	Small loch in pitchstone. 1927.
8096	(130·27) Eigg, near W. end of Sgurr ridge	Small loch in pitchstone. 1927.
8097	(131·27) Eigg, on the ridge of the Sgurr	Small lochs in pitchstone. 1927.
8098	(132·27) Eigg, W. end of Sgurr ridge with Rum behind	Shows a small loch on the pitchstone ridge. 1927.
8099	(134·27) Eigg, W. end of Sgurr ridge	'Pavement' of columnar pitchstone. 1927.
8100	(135·27) Eigg, W. end of Sgurr .	Pitchstone pavement. 1927.
8101	(114·27) Eigg, S. side of Sgurr .	Brecciated base of pitchstone. 1927.
8102	(115·27) Eigg, S. face of Sgurr .	Conglomerate below pitchstone. 1927.
8103	(116·27) Sgurr of Eigg, S.E. face .	Breccia at base of pitchstone. 1927.
8104	(107·27) Eigg, S. side of Sgurr .	Big fallen blocks of pitchstone. 1927.
8105	(113·27) Eigg, S. side of Sgurr .	Moraine of large pitchstone blocks. 1927.

8106	(196·27)	Laig Bay, Eigg . .	Hollowed dyke in Estuarine Sandstone. 1927.
8107	(197·27)	Laig Bay, Eigg . .	Hollowed dyke in Estuarine Sandstone. 1927.
8108	(199·27)	Laig Bay, Eigg . .	Inclined dyke. 1927.
8109	(201·27)	Laig Bay, Eigg . .	Dyke with raised sandstone borders. 1927.
8110	(190·27)	N. of Laig Bay, Eigg .	Intersecting dykes in Estuarine Sandstone. 1927.
8111	(192·27)	N. of Laig Bay, Eigg .	Intersecting dykes in Estuarine Sandstone. 1927.
8112	(174·27)	N. of Laig Bay, Eigg .	Sill in Estuarine Sandstone. 1927.
8113	(179·27)	Laig Bay, Eigg . .	Estuarine Sandstone with sill and concretions. 1927.
8114	(204·27)	N. of Laig Bay, Eigg .	Sill in concretionary Estuarine Sandstone. 1927.
8115	(187·27)	Laig Bay, Eigg . .	Concretions in Estuarine Sandstone. 1927.
8116	(183·27)	N. of Laig Bay, Eigg .	Concretions in Estuarine Sandstone. 1927.
8117	(185·27)	Laig Bay, Eigg . .	Concretions in Estuarine Sandstone. 1927.
8118	(188·27)	Laig Bay, Eigg . .	Concretionary Estuarine Sandstone. 1927.
8119	(176·27)	Laig Bay, Eigg . .	Undercut cliff of Estuarine Sandstone. 1927.
8120	(156·27)	Macdonald Cave, Eigg .	Raised sea-cave in basalt. 1927.
8121	(159·27)	Eilean Chasgaich, Eigg .	Basalt terraces. 1927.
8122	(161·27)	Eigg, southern end .	Banded felsite, continuation of E. pitchstone dyke. 1927.
8123	(162·27)	S. end of Eigg . .	Basalt dyke cutting dolerite sill. 1927.

KIRKCUDBRIGHT.—*Photographed by* S. H. REYNOLDS, M.A., Sc.D., *The University, Bristol.* 1/4.

8124	(29·27)	Black Laggan, Loch Dee.	Burn in spate. 1927.
8125	(33·27)	Black Laggan, Loch Dee.	Junction grit and intrusive hyperite, cascade over edge of grit. 1927.
8126	(34·27)	Black Laggan, Loch Dee.	Jointed hyperite. 1927.
8127	(32·27)	N. of Black Laggan, Loch Dee	The 'Headed stone,' a large granite erratic. 1927.
8128	(31·27)	Looking N. from Black Laggan, Loch Dee	Granite hills on left of valley, grit on right. 1927.

STIRLING.—*Photographed* by Prof. S. H. REYNOLDS, M.A., Sc.D., *The University, Bristol.* 1/4.

8129	(37·27)	Rowanclennan Point, Loch Lomond	Ice-worn rock.

IRELAND.

DUBLIN.—*Photographed by* S. H. REYNOLDS, M.A., Sc.D., *The University, Bristol.* 1/4.

8130	(20·27)	Loughshinny	Contorted Posidonomya Limestone (P). 1927.
8131	(13·27)	Loughshinny	Lane conglomerate. 1927.
8132	(23·27)	Loughshinny	Contorted Posidonomya Limestone (P). 1927.
8133	(19·27)	Loughshinny	Contorted Posidonomya Limestone (P).
8134	(17·27)	Loughshinny	Contorted Posidonomya Limestone (P).

WATERFORD.—*Photographed by* P. B. ROBERTS, B.M./F.K.R.S., *W.C.* 1. 1/4.

8135	(5) Coumshinaun, Comeragh Mountains	Cirque with moraine-dammed lakelet. 1926.
8136	(6) Coumshinaun, Comeragh Mountains	Scenery of well-jointed Old Red Sandstone. 1926.
8137	(7) Coumshinaun, Comeragh Mountains	Scenery of Old Red Sandstone country.
8138	(8) Coumshinaun, Comeragh Mountains	Old Red Sandstone mountain scenery. 1926.
8139	(9) Coumshinaun, Comeragh Mountains	Chimney in horizontal well-jointed Old Red Sandstone.
8140	(10) Coumshinaun, Comeragh Mountains	Lakelet and Old Red Sandstone precipice.
8141	(11) The Three Lakes, Comeragh Mountains	Cirque with lakelet.

WICKLOW.—*Photographed by* P. B. ROBERTS, B.M./F.K.R.S., *W.C.* 1. 1/4.

8142	(4) Upper Lake, Glendalough .	Lake in glaciated valley.
8143	(3) Glenmalune	Long straight glaciated valley. 1926.
8144	(2) Art's Lough, S. of Glenmalune	Hanging valley with lakelet. 1926.
8145	(1) Valley to S. at upper end of Glenmalune	Moraine in hanging valley. 1926.

The Old Red Sandstone Rocks of Kiltorcan, Ireland.—*Report of Committee* (Mr. W. B. Wright, *Chairman*; Prof. T. Johnson, *Secretary*; Dr. W. A. Bell, Dr. J. W. Evans, C.B.E., F.R.S., Prof. W. H. Lang, F.R.S., Sir A. Smith Woodard, F.R.S.). *Drawn up by the Secretary.*

The difficulty under which the investigation of the Upper Devonian Plants of Kiltorcan, Co. Kilkenny, has been conducted will be realised when it is mentioned that it is only within the last few months that many of the specimens of 1914 have become available for inspection, owing to the occupation by the authorities (civil and military) of the botanical division of the college. Summary ejection prevented the removal of the material. In consequence only such material as could be sent up by the quarryman has been examined, and comparison with stored material was impossible.

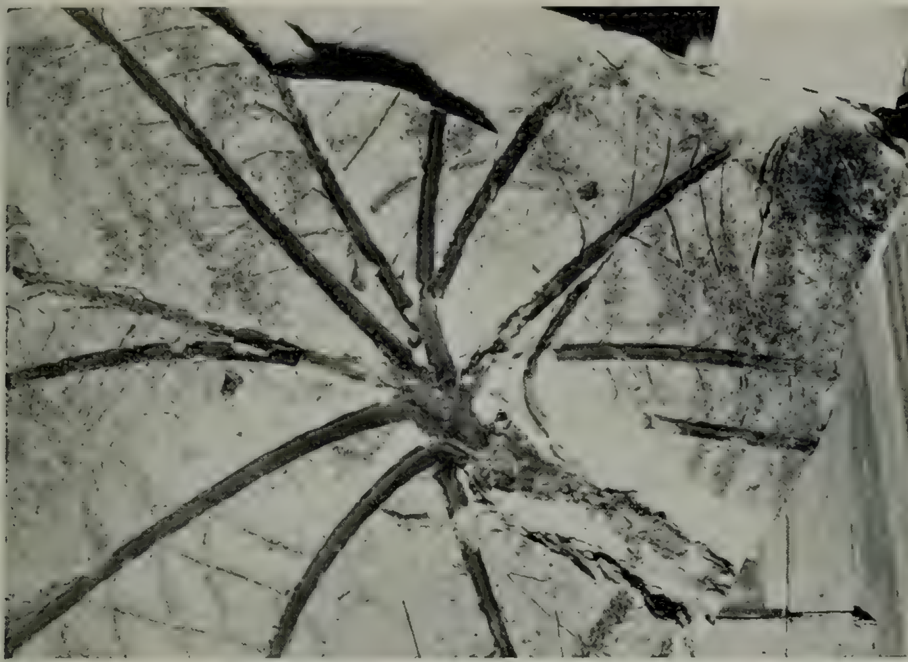
The results of examination of material show that the contents of the quarry are not exhausted, and as the beds are steadily disappearing as *road-repairing* material (a *sin* according to the late Dr. Kidston) it will soon be too late to get further supplies. It is necessary either to purchase the site and stop the exploitation (there is plenty of ordinary road stone available) or to arrange to make an exploration of the quarry, lasting a week or two with two or three quarrymen at work. The quarryman is naturally unable to pick out special specimens required or revealed, and sends up much ordinary *Archæopteris* and *Bothrodendron*. Specimens of these are still available for free distribution to any institution or authority interested.

Archæopteris hibernica.—Considerable advance in the examination of this genus can be reported. *The discovery of fertile fronds*, hitherto found always detached, *on a stem*, as the photograph shows, is of importance. There are in all about fourteen fronds, partly sterile, attached to the stem. They do not form a terminal rosette, but appear as if the stem impression had been split obliquely. The stem is 2–3 cm. wide, shows a pith apparently, and is pericaulomic. The frond has a polydesmic petiole, adnate stipules and ramenta, often seen in edge only as a fine line just above the stipules. The pinnule of the bipennate leaf, 5 feet long, is triangular–rhomboidal, 3×1 cm., and in favourable cases shows a flabellate venation which is as pronounced as that of *Ginkgo*. The pinnule is attenuated, sub-sessile and decurrent. The forking veins in two groups in the lamina unite into one main vein entering the rachidule usually. Knowledge of this venation is necessary to understand the fertile state, as there are to be found all stages of transition from the purely vegetative pinnule to the completely fertile one. The *sporangium* is a lineal or oval body $2 \times \cdot 5$ mm. on an average, on a vascular stalk. It shows, in favourable cases, a longitudinal striation (vascular in part ?) and dehisces longitudinally. There are cases where it appears transversely barred or septate, but the conclusion I am forced to is that this condition is artificial.

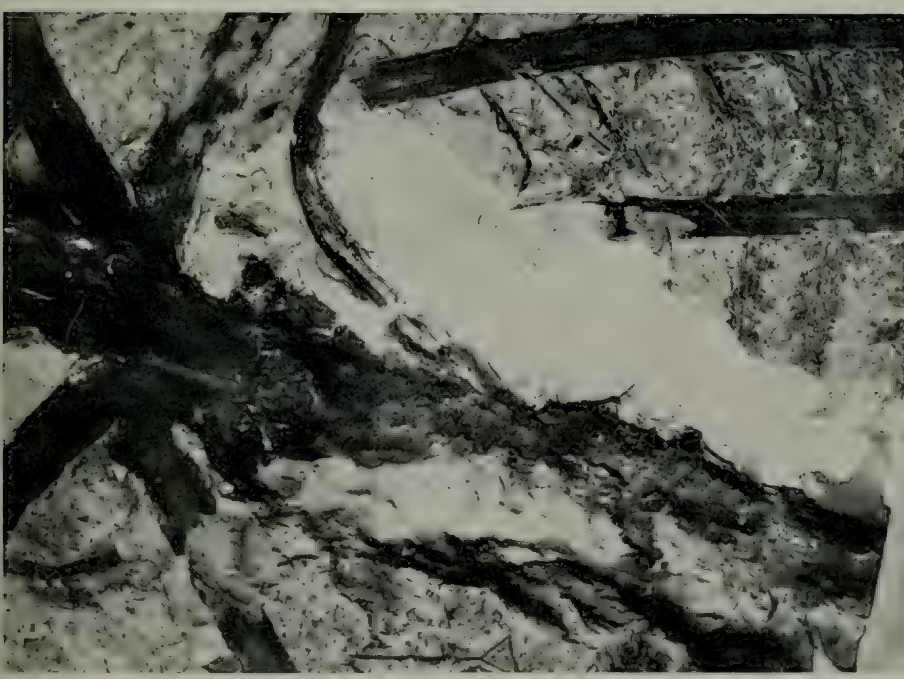
Restoration shows *two kinds of spores*: one—50μ in diameter—with pitted wall and a round-triangular shape; the other kind is spherical, smooth-walled and only 20μ in size. These two kinds were obtained from several restored specimens, and I am led to conclude that *Archæopteris* was not a pteridosperm but a *heterosporous* fern, with megaspores and microspores, that it had the habit of a *tree-fern* and not of a *Marattia* or *Angiopteris*, spite of stipule, with a climbing habit, if certain stems found at Kiltorcan are rightly attributed to it.

The other most interesting addition is the discovery of several specimens in a fertile state, which remind me forcibly of the *Dimeripteris* of Schmalhausen from the Devonian Donetz beds in Russia. The photograph shows a ribbon-like, repeatedly forked body, the ultimate forks showing ovate or club-shaped sporangia at the ends of the prongs. These sporangia yield spores of two kinds, scarcely distinguishable from those of *Archæopteris*. Occasionally one sees signs of sterile pinnules suggestive of *Sphenopteris Hookeri*, but for the present it is better to call the specimens *Dimeripteris hibernicus*. The small *round sporangia* associated with the *seed-impressions* of *Spermolithus devonicus* have yielded spores. I cannot yet assign this fertile state to any known genus.

I have been steadily at work, as far as our disturbed state allowed, since 1916, at the Washing Bay and other localities yielding *Tertiary Plants*, and hope to be in a position soon to publish results.



Archæopteris Hibernica. Stem bearing fertile fronds ($\frac{1}{6}$).



Archæopteris stem showing frond attachment ($\frac{1}{1}$).

Illustrating Report on The Old Red Sandstone Rocks of Kiltorcan, Ireland.

[*To face* p. 394.

Great Barrier Reef.—*Report of Committee* (Rt. Hon. Sir M. NATHAN, *Chairman*; Prof. J. STANLEY GARDINER *and* Mr. F. A. POTTS, *Secretaries*; Hon. JOHN HUXHAM, *Treasurer*; Mr. E. HERON ALLEN, Dr. E. J. ALLEN, Prof. J. H. ASHWORTH, Dr. G. P. BIDDER, Dr. R. N. RUDMOSE BROWN, Dr. W. T. CALMAN, Sir G. LENOX CONYNGHAM, Sir EDGEWORTH DAVID, Mr. F. DEBENHAM, Admiral DOUGLAS, Capt. EDGELL, Prof. F. E. FRITSCH, Prof. W. T. GORDON, Sir S. F. HARMER, Sir FRANK HEATH, Mr. A. R. HINKS, Dr. MARGERY KNIGHT, Prof. A. C. SEWARD, Dr. HERBERT H. THOMAS, Dr. C. M. YONGE) *appointed to organise an expedition to investigate the biology, geology and geography of the Australian Great Barrier Reef.*

THE Great Barrier Reef Committee met six times in the year. They co-opted Sir Frank Heath and Captain Edgell, whose assistance is gratefully acknowledged. The Empire Marketing Board made a grant of £2,500 towards the purposes of the Expedition, and the Australian Government met this by a similar donation. Other contributions amount to £2,750, including Great Barrier Reef Committee £1,000, Royal Society £450, Australian Association for the Advancement of Science £200, Zoological Society £100, Dr. Bidder £500, Mr. E. T. Browne £100, Lord Glendyne £100, and Mr. Heron Allen £100, together with the grant from the Association. Cambridge University undertook all expenses connected with Dr. Yonge, Balfour Student and leader of the Expedition, the British Museum of Natural History most of those connected with Mr. Tandy, and the Royal Geographical Society those concerned with the work of Mr. Steers and Mr. Spender in the neighbouring coastal regions. The Council for Scientific and Industrial Research of Australia has been co-operating, and with the Great Barrier Reef Committee of Australia is providing for the necessary expenses of five Australian workers to join the Expedition. The cost of boats and of camp and stores, in spite of every possible help from Australia, has proved exceptionally heavy, and the Committee is under the necessity of raising £2,000 more to meet these.

The Expedition left England on May 26 and on July 11 joined up at Brisbane. The personnel of the Expedition is as follows:—

(*a*) Dr. C. M. Yonge (Edin.), Balfour Student of the University of Cambridge, director: research on the feeding and limestone formation of corals and molluscs, and economically on the growth and feeding of molluscs, especially pearl shell.

Mr. F. S. Russell, M.A. (Cantab.), D.F.C., formerly in Fisheries of Egypt, now Naturalist to the Marine Biological Association at Plymouth: in charge of all boat work, and in particular the movements of floating organisms, both day and night, in relation to currents; six months only on Low Islands.

Dr. Orr and Dr. Marshall, Naturalists at Millport Marine Laboratory: research on varying constituents of the water such as dissolve salts, nitrates, phosphates, the *p*H, &c., in relation to diatoms and other marine plants and animals forming the basal food of fish and bottom living organisms.

Dr. Stephenson, Lecturer in Zoology in the University of London: in charge of all collections of animals and of faunistic work; special research on the growth and reproduction of corals and bottom living organisms; economically sponges, &c.

Mr. Tandy, Botanist on the staff of the Natural History Museum: in charge of the collections of all marine plants; six months only.

(Dr. Stephenson and Mr. Tandy propose to make together an œcological study of the bottom living animals and plants.)

Mr. G. W. Otter (Cantab.), volunteer; to assist the director in all matters; subsequently returning via Tahiti for comparative purposes.

Mr. Colman (Oxford), volunteer: to help Mr. F. S. Russell.

(*b*) Mr. Steers (Cantab.), University Lecturer in Geomorphology, and Mr. Spender (Oxford) attached to the Expedition as Geographers.

(*c*) Australia is adding five members to the Expedition to assist in all sections of the work.

The detailed study of the geology of the land and coast is the responsibility of Prof. Richards who has able assistants in Messrs. Bryan, Jardine, Stanley and others.

(Reports of the Great Barrier Reef Committee, Australia, Vols. I and II.) The Australian Committee, ' realising the necessity for the carrying out of marine biological work and finding it impracticable to have the work carried out by Australian biologists,' having invited the Association to undertake this side of research, all plans have been laid in this connection. Obviously, they have been largely influenced by the organisms found in the Australian boring, which reached 600 feet.

The work of the Expedition consists of direct research on the growth, feeding and reproduction of organisms around the camping island, to a large degree the sea forming a substitute for laboratory tanks. In addition, there are to be weekly or fortnightly examinations of the chemical constituents of the sea water, in particular those which concern animal and plant life. Furthermore, the study of the animals and plants of the surface waters, their numbers at different seasons, is to be undertaken. The œcological aspects of the different reefs are to be examined and the animals and plants to be collected ; this entails collecting on different reefs under diverse conditions. Furthermore, dredging and other studies in passages, in lagoons and outside the reef are to be made, as far as weather will permit, so that a proper idea may be obtained of the œcology of the organisms of the bottom in each part. In respect to this work, the reproduction of the organisms and their migrations have to be studied. Pearl shell, sponges and various other forms have to be kept under observation. While certain parts of this work of a systematic nature will be done after the return to England, all experimental work, physiological or other, must be carried on on the spot.

A camp has been erected for the Expedition on the Low Islands, near Cairns. Arrangements have been made to attach to it two launches. Obviously the naturalists in charge of the regular observations have to remain in the Cairns region. The director, acting in conjunction with Prof. Richards, has power to visit or send members of his staff to other parts of the Reef and to undertake such other work as he deems desirable. The Expedition will evacuate the camp at the end of July 1929.

The collections obtained will be worked out, so far as deemed necessary, from the systematic and morphological side, as arranged by the director in association with the Committee, except those of the bottom living plants of all sorts, which will be undertaken by the Natural History Museum. The first set of all named specimens of all groups of animals and plants is to be deposited in the Natural History Museum. The second set to be offered to the Great Barrier Reef Committee of Australia to be deposited wherever they may deem fit. All questions of economic nature are to be as fully as possible reported on *ad interim* and discussed with the appropriate authorities in Australia before the Expedition returns to England.

The Committee asks for reappointment with a grant of £200.

Animal Biology in the School Curriculum.—*Report of Committee* (Prof. R. D. Laurie, *Chairman and Secretary*; Mr. H. W. Ballance, Dr. Kathleen E. Carpenter, Prof. W. J. Dakin, Mr. O. H. Latter, Prof. E. W. MacBride, Miss M. McNicol, Miss A. J. Prothero *and* Prof. H. M. Tattersall) *appointed to consider and report upon the position of Animal Biology in the School Curriculum and matters related thereto.*

CONTENTS.

(See, further, *Appendix VII, Suggestions for Schemes of Biological Study in the Secondary School*, p. 689.)

ON BIOLOGY TEACHING IN SCHOOLS.

It is scarcely necessary at this time to labour the point that biological teaching should have *some* place in the education of our children; the principle is now very generally admitted, even though there remain a number of schools in which such teaching is limited to a little desultory 'Nature-study' in the lower forms. The question of the amount and scope of biological study to be recommended, however, requires careful attention and involves some serious consideration of the already much-worn topic of the aims and limits of school education. It would be tedious to repeat even a few of the many definitions in vogue—suffice it to remark that human education may be considered under two aspects, the vocational and the cultural, and that of these we hold that the latter is by far the most important in our schools, since (in training pupils of under sixteen years of age at least) the aim should be, first and foremost, to ensure even and healthy development of the pupil's powers, and second, to lay the foundation of a wide range of intellectual interests which may 'increase the capacity for imaginative experience.' But this should not be taken to exclude a 'realistic' or 'pre-vocational' element, which may be introduced with great advantage to the cultural aspect of the work, stimulating interest by linking the school life to life in the larger world for which it is a preparation.

The growing plant or animal in favourable natural surroundings is 'educated' to even and healthy development by the stimulating action of the various factors in its environment; it is one of the great difficulties in human education to select from the overwhelming complexities of the social and physical environment of civilised man such factors as may best afford a balanced stimulation. The guiding principle in selection should be the appeal to nature; the main endeavour, to encourage the development of the natural interests of the pupil in the order in which they naturally show themselves.

From first to last the growing child is fundamentally interested in the natural world of living creatures about him and in his own physical relations to the general life—a second interest, a concern for his own relation to the social scheme of human

life in particular, grows steadily in force especially throughout the period of adolescence. Each of these two interests can best be served and utilised by the inclusion of biological studies in the scheme of education—the second interest no less than the first, since the social and economic development of the human community is conditioned ultimately by biological laws, as an unbiassed consideration of any given political or economic problem will show.

To ensure some degree of appreciation of the interrelationships of all living things and of their ultimate dependence upon physiological and physico-chemical factors is the surest way to extend the consciousness of the pupil beyond the narrow sphere of individual entity, and to lay the foundations of a genuine and enlightened philosophy of life—'to see life steadily and see it whole'; education in its cultural aspect can have no higher aim.

But if its aim be such, biological education must be 'biological' in the fullest sense—must take as field the whole range of life, plant and animal kingdom alike[1] and man in his own place—but must not, however elementary the instruction, ever sacrifice its breadth of view. A casual lesson-series now on the butterfly, now on the buttercup, now on the kangaroo, now on the much-martyred bean-seed, dealing in no sort of sequence with such topics as the names of the parts of a flower and the number of toes on pussy's foot, will serve no purpose in the general scheme, and scarcely more will be gained even by a well-planned course in Botany alone throughout a number of years in school life; we may go farther and suggest that even parallel courses in Botany and Zoology, run on separate lines, do not constitute truly 'biological study' and will not, unless unified by the philosophic approach, contribute greatly to the end in view, if that end be cultural, as defined.

From the standpoint of intellectual training in the schools, biology has been the subject of a great deal of criticism; its methods have been stigmatised as somewhat vague and, while inculcating at best a habit of close observation, as unlikely to afford a training in accuracy of method and inductive argument equal in value to that given by the physico-chemical sciences. The answer to such a charge is best supplied by a reference to the altered trend of modern biological science which, so far from concentrating on the morphological details which once obscured its horizon, is now in large measure concerned with physiological, ecological and economic topics. The extension of our knowledge of the principles of these latter relationships has made it possible to apply them to the conduct of even quite elementary biological work, and a course arranged in such a way cannot fail to give strict training in accuracy of method as well as observation, in inductive as well as deductive reasoning.

The vocational aspect of school education is matter for serious debate; the general vocation of all pupils is citizenship, and the importance of biological studies for this end has already been urged. In the higher tops of the Elementary School, in the central School and in the middle forms of the present Secondary Schools, say from the age of twelve to sixteen, the occupations followed in the locality may with great advantage be drawn upon whenever appropriate, as for example in Agricultural districts, without rendering the training 'vocational' in the proper sense of the word.[2] With regard to special vocational studies, we think that such should not be undertaken by pupils under the age of fifteen or sixteen.

To summarise, some general guiding principles may be set forward, as follows:—

1. The general aim of school studies in Biology should be to inculcate a sound appreciation of the natural laws which govern the lives of human beings no less truly than they do those of other animals and of plants.

2. The basis of the study should be close observation of plants and animals in relation to their natural environment, and not as self-contained entities.

3. Morphological study should be undertaken less for its own sake than for that of its fundamental importance in the study of organic function.

The actual building of a detailed scheme of work to range throughout the school in accordance with those principles requires a great deal of close discussion. The following general suggestions are made:—

(*a*) The biological work of lower forms should consist mainly of direct observational study of plants and animals on heuristic lines and using living specimens whenever

[1] This has been recognised in other countries more than here. See Appendix VI.

[2] We would take this opportunity of expressing ourselves in sympathy with the general suggestions made in the 'Report of the Consultative Committee on the Education of the Adolescent.' Board of Education. H.M. Stationery Office. 1926.

possible; simple morphological study should be throughout related to physiological and ecological principles, growing plants and living animals (such as pond-animals, earthworms, &c.) should be kept in the classroom and collected and tended by the pupils themselves, and visits to museums, parks and botanical and zoological gardens should be made as frequent as possible.

(*b*) Biological study in the middle school should be correlated with work in elementary Physics and Chemistry; a special feature should be made of simple experiments illustrating the fundamental processes of respiration, assimilation, &c., in plants and animals alike, and their essential similarity to the corresponding processes in man should be emphasised. The ease with which a number of physiological principles can be demonstrated on the human subject should be borne in mind. The idea of evolution should be implicit, and some indication given of the interrelations of biology and social science. At this stage the human occupations, particularly those followed in the locality, should be drawn upon as providing mental stimulus.

(*c*) For pupils above the age of sixteen more detailed morphological study of animals and plants should be undertaken, but the greatest importance should be attached throughout to the elucidation of the functioning of organs, and of the organism as a whole, to ecological and bionomical relationships, and to the part played by the individual and its race in the general economy of life. The interest of animals and plants as factors in human culture and civilisation should be indicated and the influence of man on the distribution of other organisms touched upon. Reference should be made to the fundamental facts of geographical palæontology. Group personal investigation work should be carried out on simple but scientific lines. Some appropriate Elementary Chemistry should be here included if the pupils have not already the requisite knowledge in this direction for a study of the desirable physiological work. The work at this stage will generally fall within the scope of Higher Certificate courses, and in view of the fact that there is an increasing tendency for the Higher Certificate to become the entrance requirement of the Universities it would appear imperative that the Universities and the school teachers should consider in co-operation the arrangement of the work in relation to both the school and University standpoints.

With regard to syllabuses, we deprecate uniformity; we would prefer to see different syllabuses elaborated in various localities in accordance with local conditions. We feel that it is fundamental to encourage individuality in teaching; on the other hand, it is desirable that the standard of achievement aimed at should be as far as possible uniform.

OUTLINE PRINCIPLES AND GENERAL SCOPE OF THE SYLLABUS IN BIOLOGY FOR PUPILS OF 11 to 16 YEARS.

The Syllabus should be drawn up in such a way as to avoid the complete separation of plants and animals into two unrelated 'kingdoms' for independent study. It should be arranged with a view to emphasising their fundamental resemblances as well as their differences, since the latter can hardly escape attention, while, unless caution be used, there is some danger that the former may be overlooked.

The study of function should be stressed throughout; morphology should be dealt with in sufficient detail (*a*) to assist in the understanding of function, (*b*) to lay the foundations necessary for a grasp of the idea of evolution.

The study of organic evolution should be implicit in the general arrangement of the syllabus, rather than a matter for separate consideration; a simple account of the struggle for existence should, however, be given.

To ensure the emergence of the idea of evolution it would perhaps be best to arrange the course so as to commence with the simpler forms of life and lead gradually up to man, but for the understanding of the relations between structure and function it is best to commence with higher types—flowering plants, frog and man, and so to proceed from the known to the unknown rather than from the simple to the complex; on balance it seems best to recommend commencing with the higher vertebrates.

Physiological experiments should be introduced not only in regard to plants but also to animals; it is a grave mistake to suppose either that animals do not lend themselves to simple experiment as readily as plants or that such experiments must involve suffering.[3] Many simple but useful physiological observations may

[3] See W. J. Dakin's 'Elements of General Zoology.' Oxford Univ. Press, 1927.

be made on the human subject direct, for example, counting the pulse and heart-beat, testing the action of saliva on starch, demonstrating the evolution of carbon dioxide in respiration, the excretory function of the skin, and a variety of observations on the senses.

Consideration should be given throughout to the relation of the organism as a whole to its natural environment and to the interrelations between all the living creatures which make up a biological community. Reference should be made, wherever possible, to local industries in their relation to the biology of human communities. Biographical notes on a few pioneers such as Darwin and Pasteur may be introduced in illustration of the relation of Biology to human affairs in general.

Practical work should include observations on living organisms in their natural surroundings, experiments on their physiology, and the keeping of aquaria, terraria, and a school garden. The use of the microscope[4] should be encouraged, but no great stress laid on the elucidation of minute structure. There should be some dissection of animal specimens sufficient to display the broader anatomical features; whether the dissection should be performed by the pupils themselves or by the teacher in their presence must be largely determined by the time and facilities available.

Instruction in the physiology of reproduction and sex should be given, but if the syllabus be well planned such instruction will occur naturally in the course of the general work, and not as a matter for special and separate consideration. Teachers are therefore relieved of the invidious task of giving the child sex instruction based upon human physiology, the essential facts being learned in ordinary school work.

ALLOTMENT OF TIME.

The following suggestions are for a four-year scheme of biological study leading to School Certificate standard, and the time allotted is considered in relation to work in Physics and Chemistry.

The ordinary number of work periods in the British School is thirty-five per week, and inquiry shows that, although there is some variation in the number of periods per week which is allotted to natural science subjects, a very usual arrangement for the four years from 12 to 16, leading to the School Certificate examinations, is four periods for the first year, six for the second, six for the third, and eight for the fourth. The following distribution of such an allotment of time between Biology, Chemistry and Physics is suggested for consideration :—

Subject.	Age 12 plus.	13 plus.	14 plus.	15 plus.
Biology	2	2	(3)	(4)
Chemistry	2 (Chemistry and Physics together)	2	(3)	(4)
Physics		2	(3)	(4)
	4	6	6	8

In the third and fourth years one of the three subjects might be discontinued, allowing each of the others to be pursued for three periods in the third year and four periods in the fourth year.

The biological work should naturally be co-ordinated with that in the other science subjects. In the earlier years the association with Physics in the more important, in the later the association with Chemistry.

The above time-table is put forward as workable in many schools under existing conditions. It is felt, however, that an arrangement which would permit all three subjects to be carried to the fourth year would be educationally desirable. The Committee invites the consideration of headmasters and headmistresses to the following scheme :—

[4] For work up to School Certificate standard a single microscope at a cost of £3 will go a long way. Such an instrument is supplied by C. Baker, 244 High Holborn, London, W.C. 1. It has a range of magnification of $\times 20$ to $\times 220$, covering ordinary 'low power' work.

Subject.	Age 12 plus.	13 plus.	14 plus.	15 plus.
Biology . . .	2	2+1	2+1	2+1
Chemistry . . .	2 (Chemistry and Physics)	2+1	2+1	2+1
Physics . . .		2+1	2+1	2+1
	4	9	9	9

The addition of six periods per week for Mathematics during each of the last three years would bring the total periods allotted to science to fifteen per week. This out of a total of thirty-five seems a very fair apportionment.

A school known to the Committee prepares for the School Certificate examinations in all three subjects with the following time-table :—

	Age 10 plus.	11 plus.	12 plus.	13 plus.	14 plus.	15 plus.
Biology . .	2	3	2	2	2	4 (alternative to Latin)
Chemistry .			2 (Chemistry and Physics)	2	2	3
Physics . .				2	2	3
	2	3	4	6	6	10

An alternative adopted by some schools is the teaching of Physics and Chemistry as a combined subject, as we are advocating for Botany and Zoology in the present Report. The Oxford and Cambridge Schools Examination Board provides a School Certificate examination in Physics-and-Chemistry, the entries for which are considerably in excess of those for the Physics or Chemistry School Certificate examinations of the same Board.

APPENDIX I. OBTAINING OF SPECIMENS.

It is very desirable that, wherever possible, specimens should be collected in their natural habitat by the pupils themselves, but where this is not practicable for particular specimens, the teacher is advised to get into touch with the Departments of Zoology and Botany in one of the Universities, as it is likely that the laboratory attendant in such departments may be able either to supply the material required or to put the teacher in touch with reliable dealers.

APPENDIX II. BOOKS SUGGESTED AS SUITABLE FOR SCHOOL LIBRARIES.

There is room for some diversity of opinion as to whether a textbook, *sensu strictu*, should be in the hands of the pupils throughout the course ; while many teachers will doubtless prefer to dispense with such, at least in Junior work, and rather to encourage the compilation of notes made from original observations, all will agree that a reference library of biological works is a *sine quâ non*. In the following list

† Indicates books with a trend towards social and economic science ;

** Indicates books which may be read for mere amusement, but none the less furnish a valuable contribution to the biological background ;

*** Indicates books which may be looked upon as a nucleus in the formation of a new library.

It is obvious that still further valuable books could be listed if space permitted.

Further works are included in the *List of Books Suitable for School Science Libraries* compiled by a Joint Committee of the Science Masters' Association and the Association of Women Science Teachers, and obtainable from the Rev. T. J. Kirkland, Ki g's School, Ely (S.M.A.), and Miss M. E. Birt, St. Paul's Girls' School, Brook Green, W. 6 (A.W.S.T.), 1925, 1/1, post free. A list of books for Science Libraries, with primary reference to elementary schools, is given by John Brown in 'Teaching Science in

Schools,' Univ. London Press, 1925. A list, based on a questionnaire, is included in 'The Teaching of the Life Sciences,' published by the Friends' Guild of Teachers in 1927 (undated) and obtainable from the Secretary of the Guild, Bootham School, York, 7*d.*, post free.

Avebury, Lord, 'On British Wild Flowers, Considered in Relation to Insects.' (Macmillan, 4/6.)

Balfour-Browne, Frank, 'Concerning the Habits of Insects.' Royal Institution Lectures. (Cambridge University Press, 6/–.)

**Ballantyne, R. M., 'Martin Rattler.' (Blackie, 2/–.)

**Beebe, W., 'The Arcturus Adventure.' (Gutram, 25/–.)

***Bentham, G., and Hooker, J. D., 'Handbook of the British Flora'; revised by Rendle. (Reeve, 12/–.) 'Illustrations of the British Flora.' W. H. Fitch and W. G. Smith. (Reeve, 12/–.)

***Borradaile, L. A., 'A Manual of Elementary Zoology.' (Frowde & Hodder, 18/–.)

Bower, F. O., 'Botany of the Living Plant.' (Macmillan, 25/–.)

***—— 'Plant Life on Land, considered in some of its Biological Aspects.' (Cambridge Manuals, Cambridge University Press, 2/6.)

†—— 'Plants and Man.' (Macmillan, 14/–.)

***Calkins, G. N., 'Biology.' (Bell, 10/6.)

Carpenter, Kathleen E. 'Life in Inland Waters.' ('Text-books of Anima Biology' Series, Sidgwick & Jackson, 12/–.)

†Carr-Saunders, A. M., 'Eugenics.' (Home University Library, Williams & Norgate, 2/–.)

Coward, T. A., 'Migration of Birds.' (Cambridge University Press, 2/6.)

Cutler, D. Ward, 'Evolution, Heredity and Variation.' (Christophers, 4/–.)

***Dakin, W. J., 'Elements of General Zoology.' (Oxford University Press, 12/6.)

—— 'Introduction to Biology.' (Benn's Sixpenny Library, Benn, –/6.)

Daniel, R. J., 'Animal Life in the Sea.' (Liverpool University Press, Hodder & Stoughton, 5/6.)

***Darwin, Charles, 'The Origin of Species by means of Natural Selection.' (Murray, 7/6.)

***—— 'The Formation of Vegetable Mould through the Action of Worms.' (Murray, 7/6.)

—— His Life, told in an Autobiographical Chapter and in a Selected Series of his Published Letters. Edited by F. Darwin. (Murray, 7/6 and 5/–.)

***Dendy, A., 'Outlines of Evolutionary Biology.' (Constable, 15/–.)

**Doyle, Conan, 'The Lost World.' (Murray, 6/–.)

Elton, Charles, 'Animal Ecology.' ('Text-books of Animal Biology' Series, Sidgwick & Jackson, 10/6.)

***Fabre, J. H.: one or more books such as 'The Wonders of Instinct' (Fisher Unwin, 8/6); other books by this author are published by Hodder & Stoughton, 8/6.

Flattely, F. W., and Walton, C. L., 'The Biology of the Seashore.' (Sidgwick & Jackson, 16/–.)

Fritch, F. E., and Salisbury, E. J., 'An Introduction to the Structure and Reproduction of Plants.' (Bell, 15/–.)

——— 'An Introduction to the Study of Plants.' (Bell, 7/6.)

Furneaux, W. S., 'Life in Ponds and Streams.' (Longmans, 6/6.)

—— 'The Sea Shore.' (Longmans, 6/6.)

Gamble, F. W., 'The Animal World.' (Home University Library, Williams & Norgate, 2/–.)

***Goodrich, E. S., 'Living Organisms.' (Oxford University Press, 6/–.)

†***Gruenberg, B. C., 'Biology and Human Life.' (Ginn, 7/6.)

—— 'Elementary Biology.' (Ginn, 7/6.)

†Guyer, Michael F., 'Being Well-Born: an Introduction to Heredity and Eugenics.' Second Edition. (Constable, 21/–.)

***Haldane, J. B. S., and Huxley, Julian, 'Animal Biology.' (Oxford University Press, 6/6.)

†Hewitt, C. G., 'House Flies and how they Spread Disease.' (Cambridge Manuals, Cambridge University Press, 2/6.)

†Hodge, C. F., and Dawson, J., 'Civic Biology.' (Ginn, 8/6.)

Huxley, T. H., 'Lessons in Elementary Physiology'; revised by Barcroft. (Macmillan, 5/–.)

Johns, C. A., 'Flowers of the Field'; revised by G. S. Boulger. (S.P.C.K., 12/–.)
†Jones, H. F., 'Plant Life, Studies in Garden and School.' A Handbook for Teachers. (Methuen, 5/–.) (Of interest in relation to rural education.)
Jones, W. Neilson, and Raynor, M. C., 'A Text-book of Plant Biology.' (Methuen, 7/6.)
**Kearton, Cherry, 'My Friend Toto.' (Arrowsmith, 5/–.)
**Kearton, R., 'At Home with Wild Nature.' (Cassell, 7/6.)
***Keeble, F., 'Life of Plants.' (Oxford University Press, 5/–.)
***Keith, Arthur, 'The Engines of the Human Body.' (Williams & Norgate, 12/6.)
**Kingsley, Charles, 'The Water Babies.' (Macmillan, 1/–.)
Kinsey, A. C., 'An Introduction to Biology.' (Lippincott, 9/–.)
**Kipling, Rudyard, 'The Jungle Book.' (Macmillan. The School Kipling, 4/–.)
**—— 'The Second Jungle Book.' (Macmillan. The School Kipling, 4/–.)
Latter, O. H., 'Elementary Zoology. Part 1, Introduction to Mammalian Physiology.' (Methuen, 4/6.)
—— 'Readable School Biology.' (Bell, 2/6.)
—— 'Biology.' ('Science for All' Series, Murray, 3/6.)
Locy, W. A., 'Biology and its Makers.' (Henry Holt [Bell], 16/–.)
***Lulham, Rosalie, 'An Introduction to Zoology through Nature Study, with Directions for Practical Work. Invertebrata.' (Macmillan, 10/–.)
Lull, R. S., 'Organic Evolution.' (Macmillan, N.Y., 14/–.)
MacBride, E. W., 'Introduction to the Study of Heredity.' (Home University Library, Williams & Norgate, 2/–.)
Maeterlinck, M., 'The Life of the Bee.' (Allen & Unwin, 3/6 and 6/–.)
Mangham, S., and Sherriffs, W. Rae, 'A First Biology.' (Sidgwick & Jackson, 2/6.)
**Melville, Herman, 'Moby Dick' (A Whaling Story). (Oxford University Press, 2/–.)
***Miall, L. C., 'The Natural History of Aquatic Insects.' (Macmillan, 5/–.)
Needham, J. G., and Lloyd, J. T., 'The Life of Inland Waters.' (An Elementary Textbook of Fresh-water Biology for American Students, but very useful also for British Students.) (American Viewpoint Soc., 13 Astor Place, New York, $3, post paid.)
Newbigin, Marion J., 'Animal Geography.' (Oxford University Press, 4/6.)
—— 'Tillers of the Ground.' (Macmillan, 2/6.)
Osborn, Henry Fairfield, 'The Origin and Evolution of Life.' (Bell, 25/–.)
†Peabody, J. E., and Hunt, A. E., 'Biology and Human Welfare.' (Macmillan, N.Y., 7/–.)
Peake, H., and Fleure, H. J., 'Apes and Men.' ('The Corridors of Time' Series, Clarendon Press, 5/–.)
Peckham, G. W. and E. C., 'Wasps: Social and Solitary.' (Constable, 6/–.)
***Philip, J. B., 'Experiments with Plants.' (Clarendon Press, 3/6.)
Pitt, Frances, 'Wild Creatures of Garden and Hedgerow.' (Constable, 12/–.)
Plaskitt, F. J. W., 'Microscopic Fresh Water Life.' (Chapman & Hall, 13/6.)
Praeger, R. Lloyd, 'Weeds: Simple Lessons for Children.' (Cambridge University Press, 2/6.)
Radot, R. C., 'Life of Pasteur.' (Constable, 10/6.)
***Russell, E. J., 'Lessons on Soil.' (Cambridge Nature Study Series, Cambridge University Press, 3/–.)
Scott, D. H., 'Evolution of Plants.' (Home University Library, Williams & Norgate, 2/–.)
Sedgwick, S. N., 'The Holiday Nature Book.' (Epworth, 3/6.)
Shann, E. W., 'First Lessons in Practical Biology.' (Bell, 5/–.)
***Shipley, A. E., 'Life.' (Cambridge University Press, 5/–.)
—— 'Studies in Insect Life.' (Fisher Unwin, 10/6.)
Shipley, A. E., and MacBride, E. W., 'Elementary Textbook of Zoology. (Cambridge University Press, 30/–.)
Skene, Macgregor, 'Biology of Flowering Plants.' (Sidgwick & Jackson, 16/–.)
Stenhouse, E., 'A First Book of Nature Study.' (Macmillan, 2/6.)
—— 'An Introduction to Nature Study.' Part I, Plant Life; Part II, Animal Life. (Macmillan, each part 2/6.)
Swanton, E. W., 'British Plant Galls.' (Methuen, 10/6.)

***Tansley, A. G., 'Elements of Plant Biology.' (Allen & Unwin, 10/6.)
—— 'Practical Plant Ecology.' (Allen & Unwin, 7/6.)
Taylor, J. E., 'Flowers: Their Origin, Shapes, Perfumes and Colours.' (J. Grant, 2/6.)
***Thoday, D., 'Botany: A Textbook for Senior Students.' (Cambridge University Press, 7/6.)
Thomson, J. Arthur, 'The Study of Animal Life.' (Murray, 6/–.)
—— 'Towards Health.' (Methuen, 7/6.)
—— 'The Biology of Birds.' (Sidgwick & Jackson, 16/–.)
***Thomson, J. Arthur: One or more books, such as:—
'Biology of the Seasons.' (Melrose, 15/–.)
'The Wonder of Life.' (Melrose, 15/–.)
'The Secrets of Animal Life.' (Melrose, 9/–.)
'Natural History Studies.' (Melrose, 7/6.)
Thomson, M. and J. Arthur, 'Threads in the Web of Life.' (Macmillan, 2/6.)
Unwin, E. E., 'Pond Problems.' (Cambridge University Press, 3/–.)
Wallace, Alfred R., 'Darwinism.' (Macmillan, 8/6.)
—— 'Island Life.' (Macmillan, 8/6.)
Walter, H. E., 'Genetics.' (Macmillan, 10/–.)
Ward, H. B., and Whipple, G. C., 'Fresh Water Biology.' (Chapman & Hall, 36/–.)
***Wayside and Woodland Series (Warne):—
Coward, T. A., 'The Birds of the British Isles and their Eggs.' (1st series, 10/6; 2nd series, 10/6).
Jenkins, J. Travis, 'The Fishes of the British Isles.' (12/6.)
South, R., 'Lepidoptera of the British Isles.' Vols. I and II, Moths (12/6 each); Vol. III, Butterflies (8/6).
Step, Edward, 'Animal Life of the British Isles: Guide to Mammals, Reptiles and Batrachians.' (10/6.)
South, R., 'Wayside and Woodland Trees.' (7/6.)
—— 'Wayside and Woodland Blossoms.' 2 series. (7/6.)
Weiss, F. E., 'Plant Life and its Romance.' (Longmans, 5/–.)
Woodhead, T. W., 'A Study of Plants.' (Clarendon Press, 6/6.)

APPENDIX III. QUOTATIONS FROM RECENT GOVERNMENT DOCUMENTS.

The position of the teaching of Biology has been referred to a good deal of late in documents published by Government Departments; the following are selected extracts:—

'Natural Science in Education, being the Report of the Committee on the position of Natural Science in the Educational System of Great Britain.' H.M. Stationery Office, London, 1918. (Price 1/6.) (Sometimes referred to as the Report of the Prime Minister's Committee.)

Sect. 8 (2). Boys' Schools. 'The science teaching is in general confined to the elements of physics and chemistry; botany and zoology are, as a rule, taught only to those boys who intend to enter the medical profession.'

Sect. 41 (*a*). 'At present the curriculum up to the age of 16 in a large number of boys' schools consists of nature study in the lowest forms, followed by a laboratory course in at least one branch of physics and in chemistry; in very few boys' schools is there any attempt to give a knowledge of the main facts of the life of plants and animals . . . but no boy should leave school with the idea that science consists of chemistry and physics alone. It is agreed on almost all hands that the customary course, which is a growth of the last twenty years, has become too narrow.'

Sect. 27. Girls' Schools. In inspected girls' schools 'after a course of nature study in the earlier years, and elementary physics and chemistry between 12 and 14, botany is the subject taken from 14 or 15 onwards in the majority of schools.'

Sect. 52. All Secondary Schools. Referring to middle forms the Report runs: 'We have already laid stress on the point that some knowledge of the main

facts of the life of plants and animals should form a regular part of the teaching in every Secondary School. Systematic work in zoology, including dissection of animals and the use of the compound microscope, belongs to a later stage of school life, but the main facts as to the relation of plants and animals to their surroundings, the changes in material and energy involved in their life and growth should form part of a well-balanced school course . . . the want of teachers with wider scientific qualifications is at present the real difficulty in the introduction of biology into school work.'

Sect. 53. Girls' Schools. Part of par. 3. 'It is important that Hygiene should be well taught in girls' schools . . . the subject should be taken as late as possible in the school course, preferably at the 16–18 stage, after a course of systematic work in the sciences on which it depends.'

Sect. 110. Lack of School Training in Science. 2nd par. 'Lack of school training in Science causes not merely a loss of time at the University or Agricultural College in acquiring the elementary instead of the special training appropriate to that stage of education, but it induces a certain stiffness of mind and slowness of apprehension that is a great handicap to the technical student approaching science for the first time. . . . It is often said by University teachers that they prefer students who have learnt no science at school. This probably means no more than that they prefer the boy of all-round ability who for that very reason has remained on the classical side at school to the sort of boy who gets drafted across to science; for the type of boy intended for practical life the absence of a school training in the elements of science means a definite loss of time and opportunity in his technical training.'

'Report of an Inquiry into the Conditions affecting the Teaching of Science in the Secondary Schools for Boys in England.' Board of Education. H.M. Stationery Office, London, 1925. (Price 3*d.*)

P. 7. 'The Report of the Prime Minister's Committee on Science emphasised the need for Science teachers "with a wider outlook" (Sect. 74); it also urged the desirability of some elementary teaching of Biology as a part of the normal work of the curriculum in boys' schools. . . . Very little has been done to give effect in the schools' to the latter recommendation. 'In only three of the [39 larger boys'] schools visited is any attempt made to broaden the curriculum from 12 to 16 by the introduction of any Science subject other than chemistry and physics. This is partly due to the specialised character of the degree courses pursued by the teachers at the Universities.'

P. 8. 'The difficulty is to find teachers of Biology for boys' schools.'

P. 11. 'Only 9 of the 210 teachers [of science] teach Biology (other than the nature study sometimes taught in the lowest forms).'

P. 26. 'Two things operate to prevent the introduction of Biological Science into the Advanced Courses of most schools: (*a*) the lack of properly qualified teachers, and (*b*) the lack of suitable accommodation and laboratory equipment.'[5]

'Report of the Consultative Committee on the Education of the Adolescent.' Board of Education. H.M. Stationery Office, London, 1926. (Price 2/-.)

P. 221. 'It is, however, safe to say that most schemes for courses in elementary science in Modern Schools[6] and Senior classes[7] might be grouped round a simple syllabus consisting of:—

[5] Accommodation and laboratory equipment suitable for Botany is suitable also for Biology, and the equipment of either is much less costly than that for Physics or Chemistry. The item generally referred to as of outstanding expense is the Microscope; for work up to School Certificate standard a single microscope at a cost of £3 will go a long way. Such an instrument is supplied by C. Baker, 244 High Holborn, London. It has a range of magnification from $\times 20$ to $\times 220$, covering ordinary 'low power' work.

[6] *i.e.* Central Schools.

[7] *i.e.* of Elementary Schools.

(i) The chemical and physical properties of air, water and some of the commoner elements and their compounds, the elements of meteorology and astronomy, based on simple observations, and the extraction of metals from their ores.

(ii) A carefully graduated course of instruction in elementary physics and simple mechanics, abundantly illustrated by means of easy experiments in light, heat, sound and the various methods for the production and application of electricity.

(iii) A broad outline of the fundamental principles of biology describing the properties of living matter, including food, the processes of reproduction and respiration, methods of assimilation in plants, the action of bacterial organisms and the like.

(iv) Instruction in elementary physiology and hygiene based on lessons in Biology.'

P. 223. 'As a general rule, however, *in country schools the science syllabus both for boys and girls might be largely based on biological interests, the study of elementary physics and chemistry being subsidiary, but arranged so as to supply the indispensable foundation for a course in elementary biology with special reference to its bearing on horticulture and agriculture.* We are disposed to think that in many schools in rural areas a large part of the science course might, with advantage, be planned on the general lines indicated in Sir Edward Russell's "Lessons on Soil," with appropriate examples drawn largely from the local environment.

We suggest that science courses for girls in Modern Schools and Senior Classes should in their later stages frequently have a biological trend, though occasion should be taken to impart to the work much of the exactness and discipline of the experimental sciences and to train the girls in habits of careful observation and clear thinking. The work should not be confined to Botany, as the study of simple forms of animal life can under a wise and skilful teacher be made an admirable means of widening and disciplining the pupil's sympathies, and giving her broad hygienic ideals and a knowledge of nature which may increase her happiness and her efficiency as a human being. The courses in science for girls should be brought into connection with the instruction in hygiene and in domestic subjects, more particularly housecraft. The teachers of science and domestic subjects should keep closely in touch and collaborate in drawing up their syllabuses in these subjects.

We regard it as especially important that instruction in elementary physiology and hygiene, developing out of the lessons in elementary biology, should be given to all boys and girls in Modern Schools and Senior Classes. Such instruction should be largely the practical outcome of a study of elementary biology, treated not as a series of classifications but as the study of the development of form and function in suitable types of plant and animal life, leading up to a study of how the human body is built up and how it works. Such instruction in biology and elementary physiology, if properly carried out, might well provide the basis for a right attitude to many social problems.'

'Report of the Committee of the Privy Council for Scientific and Industrial Research for the year 1922–1923. Grants to Individuals.' H.M. Stationery Office, London.

P. 4. 'It is common knowledge that there is at present a considerable body of chemists unemployed, and the number of students who have recently graduated in chemistry is so large that many of them cannot hope to obtain satisfactory scientific employment, including teaching employment, in the near future. . . . On the other hand, there are openings for well-trained biologists and physicists, and we should be glad to be able to recommend allowances to more students to be trained in these subjects. The remedy for this state of affairs must be sought at the undergraduate stage; at the post-graduate stage it is too late. We earnestly invite the attention of all who are responsible for the direction of undergraduate studies to the enormous importance of considering, in the interests of the nation as well as of the students themselves, the prospects of employment which different branches of scientific study offer.'

Extract from circular letter from the Private Secretary (Appointments [8]), Colonial Office, covering Memorandum on 'Agricultural, Forestry, Veterinary and other Scientific Appointments in the Colonial Service' (Colonial Office, March 1927) :—

> 'last year, for instance, it was not possible for the Secretary of State to award a scholarship in Entomology as no candidate who had taken Honours in Zoology, or some other appropriate course, was forthcoming.'

APPENDIX IV. CURRENT SYLLABUSES OF BIOLOGY, BOTANY, AND ZOOLOGY.

SCHOOL CERTIFICATE:

BOTANY. Syllabuses are provided by all Examining Boards.

ZOOLOGY. Syllabuses are provided by Durham, London, and Cambridge Local Examinations Syndicate; in the case of the latter under the title 'Natural History of Animals.' A few schools offer their own syllabuses for the Oxford and Cambridge Schools Examination Board.

BIOLOGY. Syllabuses are provided by Durham, London (School Cert.), Northern Universities, Oxford Local Examinations, and Wales. Syllabuses are not provided by Bristol, London (Matric.), Cambridge Local Examinations Syndicate, nor the Oxford and Cambridge Schools Examination Board; but the latter has in recent years examined a few schools on their own syllabuses, and this year a special paper was set by Bristol for one school which was examined on its own syllabus.

HIGHER CERTIFICATE:

BOTANY. Syllabuses are provided by all Examining Boards.

ZOOLOGY. Syllabuses are provided by all Examining Boards except Oxford Local Examinations.

BIOLOGY. Syllabuses are provided by all Examining Boards except Durham.

APPENDIX V. STATISTICS RELATING TO CANDIDATES ENTERING FOR BIOLOGY, BOTANY, AND ZOOLOGY IN SCHOOL CERTIFICATE, MATRICULATION, AND HIGHER CERTIFICATE EXAMINATIONS IN ENGLAND AND WALES DURING THE TEN YEARS FROM 1918 TO 1927 INCLUSIVE.

The Committee thanks the Secretaries of the various Examination Boards for their help in supplying data from which the following tables are compiled.

In the case of the University of Bristol, statistics regarding the biological subjects are only available from 1924.

[8] Some excellent Colonial appointments for botanists, mycologists, zoologists, and entomologists are at the disposal of the Secretary of State for the Colonies.

TABLE I.

Total number of Candidates entering for School Certificate and Matriculation Examinations.

Examining Authority.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Northern Universities Joint Matriculation Board:										
School Certificate	3,393	4,751	6,039	7,357	9,806	11,587	12,664	13,474	14,229	14,665
Matriculation .	1,235	1,141	1,060	888	769	917	1,036	1,056	1,099	1,222
University of Bristol:										
School Certificate	61	269	351	340	419	449	434	474	471	454
University of Durham										
School Certificate	476	570	623	777	807	814	984	1,115	1,142	1,157
Matriculation .	194	296	366	378	412	351	7	8	7	7
University of London:										
School Certificate	3,082	4,329	6,245	8,183	10,325	11,431	11,838	12,740	12,888	11,522
Matriculation .	4,439	5,676	7,130	7,940	8,613	8,113	7,601	6,870	6,873	6,953
Oxford & Cambridge Schools Examination Board:										
School Certificate	2,239	3,340	4,275	5,132	5,744	6,283	7,239	7,626	8,699	7,982
Oxford Local Exams.:										
School Certificate	9,275	9,215	9,274	10,263	10,706	11,168	11,716	12,188	12,770	12,876
Cambridge Local Exams. Syndicate:										
School Certificate	6,805	6,711	7,784	8,691	8,979	8,951	9,417	9,475	9,418	9,384
Central Welsh Board:										
School Certificate	2,244	2,403	2,761	3,319	3,609	3,772	3,813	3,929	4,285	4,918
University of Wales:										
Matriculation .	120	136	202	273	263	213	243	200	121	259
	33,563	38,837	46,110	53,541	60,452	64,049	66,992	69,155	72,002	71,399

TABLE II.

Total number of Candidates entering for Higher Certificate Examination.

Examining Authority.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Northern Universities Joint Matriculation Board . .	235	481	913	1,359	1,685	1,975	2,111	2,210	2,590	2,675
University of Bristol	—	39	41	107	114	125	164	130	160	161
University of Durham	6	15	38	65	78	82	79	96	116	140
University of London	—	63	211	500	723	880	1,027	1,205	1,311	1,511
Oxford & Cambridge Schools Examination Board . .	568	810	1,202	1,531	1,628	1,817	1,923	2,012	2,106	2,198
Oxford Local Examinations . .	82	131	170	263	264	219	304	375	446	513
Cambridge Local Examinations Syndicate . . .	69	142	214	392	462	473	545	545	657	651
Central Welsh Board	343	416	525	434	451	516	476	532	501	539
	1,303	2,097	3,314	4,651	5,405	6,087	6,539	7,105	7,887	8,388

TABLE III.

Entries for School Certificate and Matriculation Examinations in Botany.

Examining Authority.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Northern Universities Joint Matriculation Board:										
School Certificate	800	1,292	1,692	1,920	2,735	3,224	3,547	3,789	3,788	3,490
Matriculation .	182	122	115	64	68	68	58	65	87	115
University of Bristol:										
School Certificate	—	—	—	—	—	—	104	124	128	118
University of Durham										
School Certificate	—	134	132	117	117	111	218	185	207	211
Matriculation .	6	13	4	9	9	4	—	—	—	—
University of London:										
School Certificate	767	1,131	1,454	1,943	2,495	2,728	3,212	3,322	3,283	3,320
Matriculation .	582	631	880	1,086	1,102	1,065	963	751	726	751
Oxford & Cambridge Schools Examination Board:										
School Certificate	157	201	298	418	385	360	391	461	438	400
Oxford Local Examinations:										
School Certificate	2,751	2,590	2,817	3,035	3,450	3,964	3,887	3,797	3,973	3,824
Cambridge Local Examinations Syndicate:										
School Certificate	2,417	2,250	2,614	3,095	2,976	2,729	2,720	2,328	2,441	2,435
Central Welsh Board:										
School Certificate	797	760	912	1,041	1,014	1,123	1,084	1,031	1,017	1,131
University of Wales:										
Matriculation .	1	3	5	17	14	15	19	7	10	34
Total entries—Botany . .	8,460	9,127	10,923	12,745	14,365	15,391	16,203	15,860	16,098	15,829
Total candidates .	33,563	38,837	46,110	53,541	60,452	64,049	66,992	69,155	72,002	71,399

TABLE IV.

Entries for School Certificate and Matriculation Examinations in Biology (under the name 'Natural History' in Northern Universities Joint Matriculation Board).

Examining Authority.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Northern Universities Joint Matriculation Board:										
School Certificate	94	55	102	127	233	245	291	359	418	535
Matriculation .	23	43	23	7	13	5	19	11	16	15
University of Bristol:										
S. Cert. (no syl.) .	—	—	—	—	—	—	—	—	—	—
University of Durham										
School Certificate	—	—	—	—	—	—	14	11	47	33
Matriculation .	—	—	—	—	—	—	2	2	1	—
University of London:										
School Certificate	—	—	—	—	—	—	2	18	52	84
Matric. (no syl.) .	—	—	—	—	—	—	—	—	—	—
Oxford & Cambridge Schools Examination Board:										
School Certificate	—	—	—	—	—	—	—	21	10	24
Oxford Local Examinations:										
School Certificate	—	—	—	—	—	—	—	—	26	34
Cambridge Local Examinations Syndicate:										
S. Cert. (no syl.) .	—	—	—	—	—	—	—	—	—	—
Central Welsh Board:										
School Certificate	—	—	—	—	20	16	18	30	39	48
University of Wales:										
Matriculation .	—	—	—	—	—	—	—	—	1	1
Total entries—Biology . .	117	98	125	134	266	266	346	452	610	774
Total candidates .	33,563	38,837	46,110	53,541	60,452	64,049	66,992	69,155	72,002	71,399

TABLE V.

Entries for School Certificate or Matriculation Examinations in Zoology (under the name 'Natural History of Animals' in Cambridge Local Examinations Syndicate).

Examining Authority.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Northern Universities Joint Matriculation Board:										
S. Cert. (no syl.) .	—	—	—	—	—	—	—	—	—	—
Matric. (no syl.) .	—	—	—	—	—	—	—	—	—	—
University of Bristol:										
S. Cert. (no syl.) .	—	—	—	—	—	—	—	—	—	—
University of Durham										
School Certificate	—	8	—	—	—	—	—	—	1	—
Matriculation .	2	2	—	2	1	—	—	—	—	—
University of London:										
School Certificate	—	—	—	3	2	—	4	11	6	4
Matriculation .	13	16	24	25	27	34	22	16	29	20
Oxford & Cambridge Schools Examination Board:										
School Certificate	—	—	—	—	—	—	22	15	20	9
Oxford Local Examinations:										
S. Cert. (no syl.) .	—	—	—	—	—	—	—	—	—	—
Cambridge Local Examinations Syndicate:										
School Certificate	28	59	58	75	46	69	59	64	61	74
Central Welsh Board:										
S. Cert. (no syl.)	—	—	—	—	—	—	—	—	—	—
University of Wales:										
Matric. (no syl.) .	—	—	—	—	—	—	—	—	—	—
Total entries—Zoology . .	43	85	82	105	76	103	107	106	117	107
Total candidates .	33,563	38,837	46,110	53,541	60,452	64,049	66,992	69,155	72,002	71,399

TABLE VI.

Total Entries in England and Wales for School Certificate and Matriculation Examinations in Botany, Biology and Zoology respectively, from 1918 *to* 1927 *inclusive.*

Subject.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Botany .	8,460	9,127	10,923	12,745	14,365	15,391	16,203	15,860	16,098	15,829
Biology .	117	98	125	134	266	266	346	452	610	774
Zoology .	43	85	82	105	76	103	107	106	117	107

TABLE VII.

Entries for Higher Certificate Examination in Botany (whether as Principal or Subsidiary Subject).

Examining Authority.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Northern Universities Joint Matriculation Board . . .	24	84	135	196	237	241	298	279	300	320
University of Bristol	—	—	—	—	—	—	3	5	11	10
University of Durham	—	—	4	4	1	4	6	5	4	2
University of London	—	—	15	26	41	71	69	114	117	135
Oxford and Cambridge Schools Examination Board . .	10	22	32	51	54	45	41	36	51	55
Oxford Local Examinations . . .	2	5	27	22	46	24	45	80	67	77
Cambridge Local Examinations Syndicate . . .	2	6	11	17	26	21	25	18	28	63
Central Welsh Board	42	68	47	47	53	47	49	66	36	39
Total entries—Botany	80	185	271	363	458	453	536	603	614	701
Total Candidates .	1,303	2,097	3,314	4,651	5,405	6,087	6,539	7,105	7,887	8,388

TABLE VIII.

Entries for Higher Certificate Examination in Biology (whether as Principal or Subsidiary Subject).

Examining Authority.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Northern Universities Joint Matric. Board	—	—	—	—	—	—	9	9	16	17
University of Bristol	—	—	—	—	—	—	6	3	3	4
University of Durham (no syllabus) .	—	—	—	—	—	—	—	—	—	—
University of London	—	—	—	—	—	—	—	6	2	4
Oxford and Cambridge Schools Exam. Board	4	7	6	7	11	46	25	47	51	53
Oxford Local Examinations . .	—	—	—	—	—	—	2	—	—	2
Cambridge Local Examinations Syndicate . . .	—	—	3	9	5	4	2	1	3	6
Central Welsh Board	3	—	1	1	3	3	4	3	4	3
Total entries—Biology	7	7	10	17	19	53	48	69	79	89
Total Candidates .	1,303	2,097	3,314	4,651	5,405	6,087	6,539	7,105	7,887	8,388

TABLE IX.

Entries for Higher Certificate Examination in Zoology (whether as Principal or Subsidiary Subject).

Examining Authority.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Northern Universities Joint Matric. Board	6	26	24	34	60	61	63	61	87	75
University of Bristol	—	—	—	—	—	—	3	2	3	3
University of Durham	—	—	—	—	—	—	1	—	2	1
University of London	—	—	—	5	4	19	16	29	41	61
Oxford and Cambridge Schools Exam. Board	—	2	6	26	12	16	22	13	26	36
Oxford Local Examinations (no syllabus)	—	—	—	—	—	—	—	—	—	—
Cambridge Local Examinations Syndicate . . .	—	—	—	—	8	6	4	1	8	10
Central Welsh Board	—	—	—	5	3	2	6	8	—	8
Total entries—Zoology	6	28	30	70	87	104	115	114	167	194
Total Candidates .	1,303	2,097	3,314	4,651	5,405	6,087	6,539	7,105	7,887	8,388

TABLE X.

Total Entries in England and Wales for Higher Certificate Examinations in Botany, Biology, and Zoology respectively, from 1918 to 1927 inclusive.

Subject.	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Botany . .	80	185	271	363	458	453	536	603	614	701
Biology . .	7	7	10	17	19	53	48	69	79	89
Zoology . .	6	28	30	70	87	104	115	114	167	194

TABLE XI.

Relative Numbers of Entries in England and Wales for Botany, Biology, and Zoology respectively, expressed in percentages.

School Certificate or Matriculation.

Years.	Botany.	Biology.	Zoology.
	%	%	%
1918	98·2	1·3	0·5
1919	98·0	1·1	0·9
1920	98·2	1·1	0·7
1921	98·2	1·0	0·8
1922	97·7	1·8	0·5
1923	97·6	1·7	0·7
1924	97·3	2·1	0·6
1925	96·6	2·8	0·6
1926	95·7	3·6	0·7
1927	94·8	4·6	0·6

Higher Certificate.

Year.	Botany.	Biology.	Zoology.
	%	%	%
1918	85	8	7
1919	84	3	13
1920	87	3	10
1921	81	4	15
1922	82	3	15
1923	74	9	17
1924	77	7	16
1925	77	9	14
1926	72	9	19
1927	71	9	20

APPENDIX VI. POSITION OF BIOLOGICAL TEACHING IN SECONDARY SCHOOLS IN OTHER COUNTRIES.

Secondary Schools in France.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry.

The following Table is compiled from data given in *Horaires Programmes Instructions* 1925, *Enseignement Secondaire* (Colin, Paris, 1925), in which syllabuses also are given.

Table I.

Scheme showing hours per week allotted to Natural Science subjects, in Lycées et Collèges des garçons. Ages 10 *or* 11 *to* 17 *or* 18.

	VI.	V.	IV.	III.	II.	I.	Alternative classes: Philosophie	Alternative classes: Mathematiques
Biology .	1 or 2 (Animals and Plants)	1 or 2 (Animals and Plants)	—	1 (Human Physiology and Hygiene)	—	—	2 (Animal Physiology, especially human. Plant physiology)	
Geology .	—	—	1	—	—	—	—	
Physics and Chemistry .	—	—	—	—	4	4½	4½ or 6	

On the modern side a second hour per week is allotted under VI. and V. for practical work in Biology.

The same scheme obtains for Lycées et Collèges des jeunes filles, except that in II, I, and Philosophie, half an hour less is allowed for practical work in Physics and Chemistry.

Secondary Schools in Prussia.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry.

There are four types of 9-year secondary schools for boys and four for girls ranging in each case from the predominantly classical school with Latin and Greek (Gymnasium and gymnasiale Studienanstalt) through those with Latin, but not Greek (Realgymnasium, Reformrealgymnasium, realgymnasiale Studienanstalt) to those with neither Latin nor Greek (Oberrealschule, Oberlyzeum der Oberrealschulrichtung, Lyzeum, and Oberlyzeum). In each type Biology is one of the fundamental subjects. Thus it is included in all during the three junior years, from the age of 10 to 13, a good level of attainment being reached. During the two following years it gives place to Physics. It is then resumed together with Chemistry, and leads to human physiology and general and sex hygiene (age 15–16 years). Further work, leading to a greater appreciation of its cultural and economic aspects, is carried out in all the schools, and in the Oberschule aspects are included demanding a more thorough knowledge of Chemistry. The following Table is adapted from *Richtlinien fuer die Lehrplaene der hoeheren Schulen Preussens, herausgegeben von Richert* (2 *Baende*) (Berlin, Weidmann, 1927), which also gives outline syllabuses.

TABLE II.

Prussian Scheme for Natural Science subjects showing hours of instruction per week. The first four types of school are for Boys and the last four for Girls. Ages from 10 *to* 19.

	Class	VI.	V.	IV.	U III.	O III.	U II 1 2 Halbjahr	O II 1 2 Hbjr	U I 1 2 Hbjr	O I 1 2 Hhjr
Gymnasium	Physics	–	–	–	2	2	– –	– 2	2	2
	Chemistry	–	–	–	–	–	2	– –	– –	– –
	Biology	2	2	2	–	–	– –	2 –	– –	– –
Realgymnasium	Physics	–	–	–	2	2	2 –	– 3	2	2
	Chemistry	–	–	–	–	–	2	– –	2	2
	Biology	2	2	2	–	–	– 2	3 –	– –	– –
Reformrealgymnasium	Physics	–	–	–	2	3	– –	– 3	– 3	– 3
	Chemistry	–	–	–	–	–	3 –	– –	3 –	3 –
	Biology	2	2	2	–	–	– 3	3 –	– –	– –
Oberrealschule	Physics	–	–	–	2	3	3 –	3	3	3
	Chemistry	–	–	–	–	–	3	3	– 3	– 3
	Biology	2	2	2	–	–	– 3	–	3 –	3 –
Gymnasiale Studienanstalt	Physics	–	–	–	2	2	– –	2	– 2	– 2
	Chemistry	–	–	–	–	–	2 –	– –	2 –	– –
	Biology	2	2	2	–	–	– 2	– –	– –	2 –
Realgymnasiale Studienanstalt	Physics	–	–	–	2	2	– –	– 3	– 3	– 3
	Chemistry	–	–	–	–	–	2 –	3 –	3 –	– –
	Biology	2	2	2	–	–	– 2	– –	– –	3 –
Oberlyzeum der Oberrealschulrichtung	Physics	–	–	–	2	3	– –	2	2	3
	Chemistry	–	–	–	–	–	3 –	2	– 3	– 2
	Biology	2	2	2	–	–	– 3	– –	3 –	2 –
Lyzeum (to end of U II) und Oberlyzeum	Physics	–	–	–	2	3	– –	– 3	– 3	– 3
	Chemistry	–	–	–	–	–	3 –	– –	3 –	– –
	Biology	2	2	2	–	–	– 3	3 –	– –	3 –

SECONDARY SCHOOLS IN SAXONY.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry.

In Saxony there are eight types of secondary schools. All these are mixed schools excepting the Hoehere Maedchenschule. Excepting in the case of the Aufbauschule the pupils go to the secondary school at the age of 10; to the Aufbauschule, which is a continuation of the elementary school, they go at the age of 13. The Reformgymnasium, the Reformrealgymnasium, the Deutsche Oberschule and the Aufbauschule are post-Revolution types of school.

An especially interesting feature is the intimate way in which Natural History and Chemistry are associated in all the types of schools. Generally speaking, the natural history of plants and animals forms the sole Natural Science teaching for the first four years and a combined course of Natural History and Chemistry extends over the last five years. The study of human physiology and hygiene is emphasised.

The following Table is compiled from *Zur Neuordnung des hoeheren Schulwesens in Sachsen. Denkschrift des Ministeriums fuer Volksbildung Meinhold u.Soehne, Dresden,* 1926. The types of schools have been arranged in order from the predominantly classical to the predominantly modern one.

TABLE III.

Saxon Scheme for Natural Science subjects showing hours of instruction per week. All are mixed schools except the 'Hoehere Maedchenschule.' Ages 10–19.

	Class	VI.	V.	IV.	UIII.	OIII.	UII.	OII.	UI.	OI.
Gymnasium	Biology	} 2	2	2	1	1	1	1 or (a) – (d) 1	2 or (a) – (d) 2	1 or (a) – (d) 2
	Chemistry									
	Physics	–	–	–	–	–	2	2	2	2
	Prac. Nat. Sci. winter	–	–	–	–	1	–	1	1	1
Reform-gymnasium	Biology	2	2	2	2	} 2	1	1 or (a) – (d) 2	2 or (a) – (d) 2 (a) – (d) 2	2 or (a) – (d) 2 (a) – (d) 2
	Chemistry	–	–	–	–					
	Physics	–	–	–	–	2	2	2	1	1
	Prac. Nat. Sci. winter	–	–	–	–	1	–	1	1	1
Real-gymnasium	Biology	2	2	2	2	} 2	2	2 or (a) – (d) 2 (a) 1 (d) 2	2 or (a) – (d) 2 (a) 1 (d) 2	2 or (a) – (d) 2 (a) 1 (d) 2
	Chemistry	–	–	–	–					
	Physics	–	–	–	–	2	2	2	3	2
	Prac. Nat. Sci. winter	–	–	–	–	1	–	1	1	1
Reform-real-gymnasium	Biology	2	2	2	2	} 2	2	2 or (a) – (d) 2 (a) 1 (d) 2	2 or (a) – (d) 2 (a) 1 (d) 2	2 or (a) – (d) 2 (a) 1 (d) 2
	Chemistry	–	–	–	–					
	Physics	–	–	–	–	2	2	2	3	2
	Prac. Nat. Sci. winter	–	–	–	–	1	–	1	1	1
Oberreal-schule	Biology	2	2	2	2	} 2	3	3 or (a) 2 (c) 2 (d) 4	3 or (b) 2 (c) 2 (d) 4	3 or (b) 2 (c) 2 (d) 4
	Chemistry	–	–	–	–					
	Physics	–	–	–	–	3	3	3	3	2
	Prac. Nat. Sci. winter	–	–	–	–	1	–	1	1	1
Deutsche Oberschule	Biology	2	2	2	2	3	} 3	2 or (a) 1 (d) 2	2 or (a) 1 (d) 2	2 or (a) 1 (d) 3
	Chemistry	–	–	–	–	–				
	Physics	–	–	–	–	–	–	3	3	3
	Prac. Nat. Sci. winter	–	–	–	–	1	–	1	1	1
Aufbau-schule	Biology	–	–	–	3	4	} 3	3	3	3
	Chemistry	–	–	–	–	–				
	Physics	–	–	–	–	–	2	2	2	2
	Prac. Nat. Sci. winter	–	–	–	–	–	–	1	1	1
Hoehere-Maedchen-schule	Biology	2	2	2	} 3	3	3	3 or (b) 2 (c) 3 (d) 4	3 or (b) 1 (c) 3 (d) 4	2 or (b) 1 (c) 2 (d) 4
	Chemistry	–	–	–						
	Physics	–	–	–	1	2	2	3 or (b) 2 (c) 2 (d) 3	3 or (b) 2 (c) 2 (d) 3	2 or (b) 2 (c) 2 (d) 2
	Prac. Nat. Sci. winter	–	–	–	–	–	–	–	–	–

In most of these schools the three upper Forms are divided into several groups taking different, ndamental subjects :—(a) History and Languages; (b) Latin; (c) Modern Languages;) Mathematics and Natural Science.

Secondary Schools in Austria.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry.

A feature of the Austrian system is the very intimate linking of subjects ; thus we find at various stages Chemistry and Physics, Biology and Chemistry, Biology and Physics, Biology and Geography.

The Allgemeine Mittelschule comprises the four upper classes (ages 10 to 14) of a new democratic type of school instituted during the recent period of reconstruction for all children of both sexes between the ages of 6 and 14 ; it is intended that it shall gradually replace classes I to IV of the Gymnasium, Lateinrealschule and Realschule.

Aufbauschule and Reform-Realgymnasium and Oberschule comprise higher forms only.

The Table is compiled from the following sources :—

Schemes 1, 2 and 3 from *Richtlinien fuer die gesetzliche Regelung des oesterreichischen Mittelschulwesens.* 1927. *Vienna : Oesterreichischen Bundesverlag.*

Scheme 4 from *Lehrplan fuer Allgemeine Mittelschulen. Vienna : Deutscher Verlag fuer Jugend und Volk.*

Scheme 5 from *Lehrplan fuer das Reform-Realgymnasium. Vienna : Deutscher Verlag fuer Jugend und Volk.*

Scheme 6 from *Lehrplaene fuer die Allgemein bildenden Oberschulen.* 1926. *Vienna: Deutscher Verlag fuer Jugend und Volk.*

Table IV.

Scheme showing hours per week allotted to Natural Science subjects. Ages 10 *to* 18.

	Class	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
1 Gymnasium .	Biology .	3	2	–	2	– 3	3	2	–
	Chemistry .	–	–	–		3 –	–	–	1
	Physics .	–	–	3	2	–	2	2	3
2 Realschule and Lateinrealschule	Biology .	3	2	–	3	2	2	2	2
	Chemistry .	–	–	–		–	2	2	2
	Physics .	–	–	3	3	–	2	3	3
3 Aufbauschule .	Biology .				–	– 3	2	2	2
	Chemistry .				2	3 –	–	–	1
	Physics .				–	–	2	2	3
4 Allgemeine Mittelschule	Biology and Chemistry [9]								
	Biol. and Mineral.	2	2	2	–				
	Chem. and Human Physiology	–	–	–	2				
	[10] Elementary Physics and Biol.	–	–	2	2				
	Elem. Physics	–	2	2	2				

[9] Some study of the solar system, geology of the soil, and distribution of plants and animals, is included in the ' Erdkunde ' of Forms I to IV.

[10] For those who do not study foreign languages.

TABLE IV (*continued*).

	Class	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
5 Reform- Real- gymnasium	Biology and Gen. Nature Knowledge								
	Plants .					2	–	–	–
	Animals .					–	2	–	–
	Human Anat., Physiol. and Hygiene .					–	–	1 –	–
	Mineralogy					–	–	– 1	–
	Allg. Erdkunde (solar system and Geol.) .					–	–	–	2
	Physics & Chemistry .					2	2	2	4
6 Oberschule (*a*) Alt-sprachliche, und (*b*) Neu-sprachliche	Allg. Erdkunde (solar system and Geol.) . .					–	–	–	1
	Chem. and Mineral. & Geol. . .					3	–	–	–
	Biology .					–	4	–	–
	Physics .					–	–	3	4
(*c*) Mathe-matisch-natur-wis-senchaft-liche	Allg. Erdkunde (solar system and Geol.) . .					–	–	–	2
	Biology								
	Botany .					2	–	–	–
	Zoology .					–	2	–	–
	Human . Physiol. .					–	–	1 –	–
	Chemistry					3	3	–	–
	Physics .					–	2	4	4
(*d*) Deutsch	Allg. Erdkunde (solar system and Geol.) . .					–	–	–	2
	Biology								
	Botany .					2	–	–	–
	Zoology .					–	2	–	–
	Human Physiol. .					–	–	1 –	–
	Chemistry .					–	2	2	–
	Physics .					–	–	3	4

SECONDARY SCHOOLS IN HOLLAND.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry.

There are seven types of Secondary School: the six-year Gymnasium, with Latin and Greek compulsory; the five-year Hoogere Burgerschool, training for University studies in medicine, mathematics, and natural science; the five-year Openbare Handelsschool, training for commerce; the three-year Hoogere Burger-

school, providing general education; the three-year Hoogere Burgerschool, training for commerce; the five-year Hoogere Burgerschool for girls, providing general education; and the four-year men and women teachers' training school, or 'Kweekschool.' The general entrance age for those schools is 12 years, excepting the 'Kweekschool' where the students enter at the age of 14.

The Table is compiled from the following sources:

Barlaeus-Gymnasium van Amsterdam, Programma van het onderwijs, gedurende den cursus 1927–1928. *Amsterdam, Stadsdrukkerij* 1927.

Programma van het onderwijs te geven aan de 3e *Hoogere Burgerschool met vijfjarigen cursus, gevestigd: Mauritskade* 58. *Cursus* 1921–1922.

Programma van het onderwijs te geven aan de Hoogere Burgerscholen met vijfjarigen cursus en gewijzigd leerplan, genaamd Eerste en Tweede Openbare Handelsschool, te Amsterdam, onderscheidenlijk gevestigd Raamplein I en P.L. Takstraat 33. *Cursus* 1924–1925.

Programma van het onderwijs te geven aan de derde Hoogere Burgerschool met driejarigen cursus te Amsterdam, Linnaeusstraat 137. *Cursus* 1927–1928.

Programma van het onderwijs te geven aan de Zevende Hoogere Burgerschool met driejarigen cursus te Amsterdam. Opleiding vor den Handel. Cursus 1921–1922.

Programma van het onderwijs te geven aan de Hoogere Burgerschool met vijfjarigen cursus voor Meisjes te Amsterdam. Cursus 1927–1928.

Programma van het onderwijs, te geven in de Afdeeling A der Kweekschool voor Onderwyzers en Onderwyzeressen te Amsterdam. Cursus 1926–1927.

TABLE V.

Schemes showing hours per week allotted to Natural Science subjects. Entrance age 12 *excepting Kweekschool.*

	Class	I.	II.	III.	IV.	V. *a b c*	VI. *a b c*
Gymnasium	Biology	3	2	—	—	— — 3	— — 2
	Chemistry	—	—	—	2	1 — 3	— — 4
	Physics	—	—	2	2	— 3 —	— — 3
Hoogere Burgerschool met vijfjarigen cursus	Biology	2	2	1	1	2	—
	Chemistry	—	—	—	4	4	—
	Prac. Chem.	—	—	—	—	2	—
	Physics	—	—	4	3	3	—
	Mechanics	—	—	—	2	2	—
Openbare Handelsschool	Biology	2	2	—	—	—	—
	Chemistry	—	—	—	2	2	—
	Physics, including Mechanics	—	—	5	—	—	—
Hoogere Burgerschool met driejarigen cursus	Biology	2	2	—	—	—	—
	Chemistry & Physics	—	—	5	—	—	—
H.B. School met driejarigen cursus opleiding vor den Handel	Natural Science	2	3	3	—	—	—
H.B. School vor Meisjes	Biology	2	2	2	2	2	—
	Chemistry & Physics	—	—	3	3	3	—
Kweekschool	Biology	—	—	2	1	2	2
	Chemistry & Physics	—	—	2	2	2	2

Secondary Schools in Belgium.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry. The study is continued throughout each year of the curriculum. There are six-year Secondary Schools of three types for boys and girls. (Athenées Royaux):—

I. Humanités modernes.
II. Humanités grecques-latines.
III. Humanités latines.

Hours of study and syllabuses are given in *Horaire et Programme des Etudes dans les Athenées Royaux.* 1926. *Ministère des Sciences et des Arts. Liège: Thone.* From these it will be found that each type includes the following course in ' Sciences physiques et naturelles.'

Table VI.

Scheme showing hours per week allotted to Natural Science subjects.

Class	VI.	V.	IV.	III.	II.	I.
Hours	2 (Botany Zoology)	2 (Botany Zoology Physics)	2 (Plant Physiology Animal Physiology Physics Chemistry)	2 (Botany Zoology Physics Chemistry)	2 (Botany Zoology Physics Chemistry)	2 (Botany Zoology Physics Chemistry)

There are also three-year Secondary Schools (Ecoles moyennes). The scheme in these covers the first three years of the six-year school course above. Particulars are given in *Horaire et Programme des Etudes dans les Ecoles moyennes de l'Etat. Ministère des Sciences et des Arts.* 1926. *Liège: Thone.*

Secondary Schools in Norway.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry.

The following particulars are from data given in *Normalplan for Byfolkeskolen. Kirke- og Undervisningsdepartementet. Stenersen: Oslo.* 1925.

Table VII.

Scheme showing hours per week allotted to Natural Science subjects in the Seven-year Primary School (Byfolkeskole). Ages 7–14.

I. II. III.	IV.	V.	VI.	VII.
	2	2	3	3
Hjemstedslaere.	(Animals	(Animals		(Animals
	and	and	—	and
	Plants)	Plants)		Plants
	—	—	—	Hygiene
	—	—	(Physics)	Physics
	—	—	—	Chemistry)

The above is the scheme for boys. That for girls is similar save that the time allotted to the subjects indicated is reduced by 1 hour in VI. and VII.

Hjemstedslaere is a practical study of the home locality, the environment in which the children are growing up, serving as a foundation for the more special study of History, Geography and Natural Science followed during the succeeding years.

The following particulars are given in *De Hoiere Almenskoler. Undervisningsplan for Middleskolen. Brogger: Oslo.* 1925.

TABLE VIII.

Scheme showing hours per week allotted to Natural Science subjects in the Three-year Secondary School (Middelskole). Ages 14–17.

Class	I.	II.	III.
Animals and Plants, including some Chemistry	3	2	—
Physics	—	—	4

Particulars regarding the various types of Gymnasia have been kindly supplied by Mr. Otto Grenness, the Kirke- og Undervisningsdepartementets skolekyndige konsulent, Oslo. They are as follows :

TABLE IX.

Scheme showing hours per week allotted to Natural Science subjects in the Three-year Gymnasium. Ages 17–20.

	Class	I.	II.	III.
Latin-linjen with Greek, Latin-linjen, Engelsk-linjen	Biology, including some Chemistry .	4	—	2
Real-linjen . .	Biology, including some Chemistry .	4	—	2
	Physics . .	—	6	6

TABLE X.

Scheme showing hours per week allotted to Natural Science subjects in the Four-year Gymnasium (Landsgymnaset).

	Class	I.	II.	III.	IV.
Latin-linjen with Greek	Biology, including some Chemistry .	½ yr. ½ yr. 5 4	Biol. 2 Chem. 3	— —	— —
Latin-linjen, Engelsk-linjen, Real-linjen	Biology, including some Chemistry .	5 4	Biol. 2 Chem. 3	— —	2 2
	Physics . .	—	—	6	6

The Parliamentary School Commission of 1922-1927 has reported in favour of the establishment of a five-year Gymnasium.

SECONDARY SCHOOLS IN SWEDEN.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry.

The Scheme for the Primary School agrees with that of Norway in including Hjemstedslaere. Particulars regarding Realskola and Gymnasium are given in 'Sweden,' a historical and statistical handbook by J. Guinchard.

The syllabus kindly supplied by the Ecklesiastik-Departementet, Stockholm, indicates that in the six-year Secondary School the number of hours per week allotted to Biology is as follows :—2 : 2 : 2 : 1 : 2 : 2.

SECONDARY SCHOOLS IN DENMARK.

Every boy and girl studies both animal and plant biology to a substantial degree, including human physiology and hygiene. The work is co-ordinated with that in Physics and Chemistry.

The Table is based on information kindly supplied by Mr. K. Heser of the Undervisningsministeriet, Copenhagen, and the pamphlet 'Schools in Denmark,' printed by J. Jorgensen & Co. Copenhagen, 1923.

TABLE XI.

Scheme showing hours per week allotted to Biology in Secondary Schools.

	Age :	11	12	13	14	15	16	17	18
Mellemskolen (4 years)	Biology .	2	2	2	2	—	—	—	—
Realklassen (1 year)	Biology .	—	—	—	—	2	—	—	—
Gymnasiet Modern Languages (3 years)	Biology .	—	—	—	—	—	2 [11]	2 [11]	2 [11]
Gymnasiet Scientific (3 years)	Biology .	—	—	—	—	—	3 [11]	3 [11]	2 [11]

The above scheme holds for both boys and girls.

Hjemstavnslaere is done in some places in the first year in the Primary School or Folkeskolen.

All children attend the Mellemskolen or Junior High School from the age of 11 to 15 for the four years. The Mellemskolen followed by one year Realklassen constitutes the Realskole giving the right to apply for Civil Service appointments and to enter some commercial, technical, and agricultural High Schools ; most of the pupils go into business.

The Mellemskolen followed by three years Gymnasiet or Senior High School constitutes the Gymnasietskole, preparing specially for the University.

SECONDARY SCHOOLS IN SWITZERLAND.

The following introductory formula is furnished by Mr. L. Chenna of the Département de l'Instruction Publique, Geneva : 'Les garçons et les jeunes filles étudient les animaux et les plantes, leur biologie ; dans certaines classes, la physiologie du corps humain ; il y a coordination entre l'étude de la physique-chimie élémentaire et celle des sciences naturelles.'

The time-table is not rigidly fixed, though it is very generally similar in schools of the same type. As illustrations the following are given :—

TABLE XII.

Scheme showing hours per week allotted to Natural Science subjects in a typical Secondary School in German-speaking Switzerland, the Staedtisches Gymnasium in Bern. Ages 15-19½.

	Class	IV.	III.	II.	I.	O.P. ½ year
Literarschule . .	Biology . .	2	2	2	1	—
	Chemistry .	—	—	—	2	2
	Physics . .	—	—	2	3	3
Realschule . .	Biology . .	2	2	2	2	—
	Chemistry .	—	—	3	2	2
	Physics . .	—	2	3	3	4

[11] In about one-third of the Gymnasiets these hours are given to Geology, Astronomy or Geography.

TABLE XIII.

Scheme showing hours per week allotted to Natural Science subjects in a typical Secondary School in French-speaking Switzerland, the Collège de Genève. Ages 12–19.

	Class	VII.	VI.	V.	IV.	III.	II.	I.
Division Inférieure	Biology	2	2	—				
	Chemistry	—	—	2				
	Physics	—	—					
Division Supérieure Classique	Biology				—	2	2(Zool)	—
	Chemistry				—	—	—	3
	Physics				—	—	2	3
Division Supérieure Réale Latine	Biology				2	3	2(Zool)	—
	Chemistry				—	—	—	4
	Physics				—	—	3	4
Division Supérieure Réale Moderne	Biology				3	4	2(Zool)	—
	Chemistry				—	—	—	4
	Physics				—	—	3	4
Division Supérieure Technique	Biology				4	3	2(Zool)	—
	Chemistry				—	—	—	4
	Physics				—	—	3	5

A good deal of information regarding Swiss Schools is contained in *Die Reform der hoeheren Schulen in der Schweiz, by Dr. Albert Barth. Kober C.F. Spittlers Nachfolger, Basel.* 1919.

SECONDARY SCHOOLS IN JAPAN.

In the *Memorandum on the Teaching of Natural History in Schools prepared by the Zoology Organisation Committee at the request of Section D of the British Association* (*Rept. Brit. Ass. Edinburgh Meeting* 1921. *London.* 1922) the following statement occurs on page 266 :—

'It is a curious fact that in England alone among civilised countries, a boy and girl can reach the age of eighteen or nineteen years and leave school without having received any school instruction in animal physiology or the natural history of animals. In Japan, to take only one example out of many, the courses in the middle school (fourteen to nineteen years of age) include Botany, Physiology and a two-years' course in Zoology. . . . And this instruction is given not only to the few scholars that are passing on to a specialised course in Science in the Universities, but to all scholars without exception.'

Brief details as to time-tables and courses of study are given in *General Description of Japanese Education, compiled for the Information Bureau of the Foreign Office at Tokyo.* 1923.

SECONDARY SCHOOLS IN THE UNITED STATES OF AMERICA.

The United States High School Curriculum is based on a system of units, each of which is a year's course, complete in itself. The pupil must acquire credit for so many units as entrance to University, 'but there are no fixed curricula and very few required courses.' This system is very roundly condemned by the writer quoted (*William S. Learned. The Quality of the Educational Process in the United States and in Europe. Carnegie Foundation for the Advancement of Teaching, Bulletin* 20. *New York.* 1927), who compares it to 'a factory system of multiple unit manufacture,' but it has its interest in the present connection as indicating the relative popularity of individual units.

Separate Botany and Zoology units have been taught in the schools for the last fifty years or so. More recently a unit of General Biology functional in outlook and related to human affairs, has been recognised[12] and has proved highly popular, rapidly

[12] Recognised as College Entrance Examination unit in November 1915.

replacing the other separated units. The following items, selected from Table IV on page 24 of C. W. Finley's *Biology in Secondary Schools and the Training of Biology Teachers, Teachers' College, Columbia University, New York City*, 1926, illustrate this. Syllabuses of Biology, Botany and Zoology courses are given in *Facilities for Foreign Students in American Colleges and Universities, by S. P. Capen, Department of the Interior, Bureau Educ., Bulletin*, 1920, *No.* 39. *Washington, Govt. Printing Office*, 1921.

TABLE XIV.

Percentage of California Day High Schools providing Botany, Zoology, and Biology respectively.

Year.	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23
Bot. .	38	31	31	31	29	27	30	31	28	32	33	27	20	17	14	11	8	9	10
Zoöl. .	16	14	12	10	11	10	12	13	13	17	17	13	5	6	5	4	3	4	3
Biol. .	—	—	—	2	—	1	1	1	4	1	3	9	32	40	46	46	47	57	60

This Table should be read in relation with Table XI in Appendix V.

The curricula for the Secondary Schools of the United States vary according to the different localities, as each State and many large cities are independent authorities for Education. The following further Table is therefore of interest :—

TABLE XV.

High School Biology. Table based on statistics furnished by the several State Departments of Education ; published in 'Turtox News' by the General Biological Supply House, 1177–79 *East* 55*th Street, Chicago, November* 1926. *The percentages given in the Table are in every case approximate.*

State.	State Board of Education recommends Course in Biology.	Percentage of Schools offering Biology.	Percentage offering Botany.	Percentage offering Zoology.
Alabama . . .	No data			
Arizona. . . .	No	80%	60%	30%
Arkansas . . .	No	80%	10%	5%
California . . .	Yes	62%	9%	3%
Colorado . . .	No data			
Connecticut . . .	Yes	No data		
Delaware . . .	Yes	100%	5%	5%
D.C.	Yes	100%	0%	0%
Florida	No	60%	30%	30%
Georgia . . .	Yes	90%	20%	5%
Idaho	Yes	40%	15%	5%
Illinois	No	50%	15%	10%
Indiana. . . .	Yes	35%	30%	5%
Iowa	No data			
Kansas	Yes	20%	15%	2%
Kentucky . . .	No data			
Louisiana . . .	Yes	100%	0%	0%
Maine	Yes	50%	10%	10%
Maryland . . .	Yes	No data		
Mass.	Yes	No data		
Michigan . . .	Yes	90%	40%	20%
Minnesota . . .	Yes	75%	10%	5%
Mississippi . . .	No data			
Missouri . . .	Yes	No data		
Montana . . .	Yes	40%	2%	2%

TABLE XV (*continued*).

State.	State Board of Education recommends Course in Biology.	Percentage of Schools offering Biology.	Percentage offering Botany.	Percentage offering Zoology.
Nebraska	Yes	20%	85%	3%
Nevada	No data			
N.H.	No	10%	2%	2%
New Jersey	Yes	90%	0%	0%
New Mexico	No	15%	15%	5%
New York	Yes	95%	8%	4%
N.C.	No data			
N. Dak.	Yes	No data		
Ohio	Yes	95%	40%	20%
Oklahoma	Yes	40%	5%	5%
Oregon	Yes	70%	15%	10%
Pennsylvania	Yes	76%	5%	2%
Rhode Island	No	No data		
S.C.	Yes	75%	0%	0%
S. Dak.	No	40%	0%	0%
Tennessee	No	No data		
Texas	No	No data		
Utah	Yes	99%	20%	20%
Vermont	No	No data		
Virginia	Yes	100%	20%	5%
Washington	No	25%	20%	5%
W. Va.	Yes	70%	10%	5%
Wisconsin	Yes	70%	15%	10%
Wyoming	Yes	5%	20%	2%

From the above it may be calculated that for the thirty-three States for which data are supplied the average percentage of schools offering Biology is 63%, the corresponding figure for Botany being 17% and for Zoology 7%.

General Conclusion. It will be seen that in all the countries of Western Europe whose position is reviewed above, instruction in Biology includes both Botany and Zoology, and that in all cases the study covers Human Physiology and Hygiene. Biology holds a position at least as important as Physics or Chemistry in Boys' Schools as well as in Girls' Schools. Every boy and girl receives substantial biological instruction.

The same holds good for Japan.

In the United States of America, where the system of free choice of 'units' obtains, the recently introduced Biology has rapidly taken the place of separate Botany and Zoology units in the very great majority of schools.

The position in England and Wales is in sharp contrast. Biology and Zoology are hardly known as school subjects. Botany does duty for all, and even Botany, though very general in Girls' Schools, is practically confined to these. Very few boys have any biological instruction in the Secondary School beyond the Nature Study which may very probably be taken during the first year of the Secondary School career. William S. Learned, in his publication already referred to, cites the following curriculum for the first five years of a Secondary School as being fairly typical of all English Boys' Secondary Schools.

Age	12	13	14	15	16
	Nature Study	—	—	—	—
	Physics	Physics	—	Physics	Physics
	—	—	Chemistry	Chemistry	Chemistry
	—	—	—	—	Mechanics

ACKNOWLEDGMENTS.

The Committee thanks the foreign State Departments of Education for valuable help received in preparing and confirming the information concerning their several countries. Its thanks are also due to the Secretaries of the various Examination Boards in England and Wales for their help, and to the Librarian of the Board of Education Library.

SUMMARY.

1. Biology is taken to include a study of both animals and plants in their natural surroundings and in the laboratory, and to cover an experimental study of function as well as a study of form ; it is taken to include also reference to human physiology and hygiene as well as to the geological history of organisms and to contacts with ordinary human affairs.

2. The Committee is strongly impressed with the high educational value of Biological Studies at school age and believe them to take a place in general education which nothing else can fill.

3. A survey of the conditions in other countries indicates that Great Britain occupies a curiously isolated position in regard to the position of Biology in the school curriculum. In all the countries of Western Europe studied except our own every boy and girl studies both animal and plant life to a substantial degree, including human physiology and hygiene ; and the same is true of Japan. The Committee is very strongly in sympathy with this practice. It notes also with much pleasure that recent publications associated with the Board of Education urge the broadening of the Science curriculum and give great prominence to Biology in this respect. It also affirms its agreement with the statement in the Report of an Enquiry published by the Board of Education and quoted on page 16 of the present Report, to the effect that one of the difficulties of the present position is ‘ the specialised character of the degree courses pursued by the teachers at the Universities.’

4. Biology and Zoology are still but little known as school subjects in England and Wales. Botany does duty for all, and even Botany, though very general in Girls' Schools, is practically confined to these.

Statistics extending over the last ten years indicate however that the number of candidates for the School Certificate and Matriculation Examinations in Biology in England and Wales is gradually increasing, whilst there is a corresponding diminution in the number of entrants for Botany, though that subject still accounts for 95 per cent. of the candidates. For Higher Certificate the number of candidates for Biology during the same period shows also a tendency to increase ; the percentage of candidates for Zoology has increased appreciably, there being a corresponding diminution in the candidates for Botany. Table XI of Appendix V should be considered in relation to Table XIV of Appendix VI, which shows how, in the United States of America, Biology, which was an almost negligible quantity in the schools prior to 1915, has since that date largely replaced separate Botany and Zoology.

5. Syllabuses in Biology, based upon a study of plants and animals, are provided by all Examining Bodies for the Higher School Certificate, but no syllabus is provided at the School Certificate stage by the University of Bristol, nor is it one of the ordinary subjects of the Oxford and Cambridge Schools Examination Board or of the Oxford Local Examinations.

6. Attention is called to the recognition of the interrelations of subjects which is shown in some of the Continental schemes, notably those of Austria and Saxony ; some study of the solar system and of geology is, for example, often associated with the study of plant and animal Natural History, and in the Saxon Schools Chemistry and Natural History are associated throughout as a single course. The Committee would welcome a movement in the schools of England and Wales in this direction. In this connection attention may also be called to the Hjemstedslaere of the Scandinavian Primary Schools.

7. A four-year scheme of biological study leading to School Certificate standard is outlined and cross reference is made to work in Physics and Chemistry.

8. The difficulty of obtaining suitable apparatus is not formidable and the expense very low as compared with that associated with the Physical Sciences. The expensive item is the microscope. For work up to School Certificate standard but little use of this instrument is required, and a single microscope at a cost of £3 will go a long way. For Higher Certificate work, when more expensive microscopes are required, very satisfactory second-hand instruments may be obtained from reliable dealers.

9. A list of books considered useful for School Libraries is given.

10. Any initial difficulties regarding the obtaining of specimens can be met by the teacher getting into touch with one of the University Departments of Zoology or Botany.

RECOMMENDATIONS.

1. It is urged that Biology should be included as a fundamental subject in the curriculum of all schools, whether for boys or for girls, so that every boy and girl should study plant, animal and human biology during several years of school life.

2. The Universities are invited :

(*a*) to note the shortage of men teachers having training in either Zoology or Botany ; also the comparative neglect in some Universities of the Zoological side of the training of women for the teaching of the Biological subjects in secondary schools ;

(*b*) to review the needs of their science students who are intending to become teachers (intending teachers form a large proportion of the students in the modern Universities) with a view to providing schemes of study related more definitely to their needs. The present Honours Degree schemes are designed to meet the requirements of specialists ; it is submitted that there is need for a more general recognition of schemes of 'general Honours' as an alternative path to a good degree. Such schemes already obtain at London and Manchester.

3. Those School Certificate and Matriculation Examination Bodies which do not at present provide syllabuses in Biology, namely, the University of Bristol, the Oxford and Cambridge Schools Examination Board, the Cambridge Local Examinations Syndicate, and the University of London Matriculation Board, are invited to consider the desirability of providing them.

ADDITIONAL REFERENCES.

It is not the purpose of the Committee to compile an exhaustive list of References, but in addition to those included in the text the following may be given.

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Vasoligation.—*Report of Committee* (Dr. F. A. E. Crew, *Chairman*; Mr. J. T. Cunningham, *Secretary*; Prof. J. S. Huxley) *for the experimental investigation of the effects of Vasoligation, &c., on the Seminal Tubules and Interstitial Tissue of the Testes of Mammals.*

Preparation of illustrated Paper on Results mentioned in last year's Report.

The autumn of last year was spent in the microscopic investigation of the vasa efferentia and the different parts of the epididymal tube, and the preparation of photomicrographs to be used as illustrations of a more detailed account of the results mentioned in the report presented last year. One of the most interesting points in the microscopical studies was the confirmation of the fact discovered by previous investigators that the seminal tubules do not terminate by open communication with the initial branches of the rete, but end in conical cellular masses which project into those cavities. The ripe sperms make their way through these cellular plugs into the cavities of the rete. The detailed paper was communicated to a meeting of the Society of Experimental Biology in December 1927, and sent to the editor of the *Journal of Experimental Biology* in January of this year. It will, I believe, appear in that journal in September next.

Grafting Experiments.

I have tried a few grafts of testes from one rat to another, but so far without much success.

December 6.—Testis from half-grown ta-rat put into scrotum of adult after removal of the original organ. The rat was killed on January 18, 1928. No recognisable remains of the graft were found.

January 31, 1928.—The host was a young mature male, the graft-rat a smaller male 13·2 cm. long. By operation from the abdomen one testis of the host was removed and a whole testis from the graft-rat fastened by a single stitch to the wall of the scrotum. In the other testis of the graft-rat sperms in movement were found in the epididymis and vas deferens, but sections showed that spermatogenesis was only beginning. The host-rat was killed on March 20, but no distinct remains of the graft were found.

February 6.—Host-rat a young mature male, the graft-rat 9·2 cm. long, excluding the tail. It was twenty-three days old. Method as before. Sections of the second testis of the graft-rat showed that the organ was quite immature, spermatogenesis not yet commenced. The host was killed on March 20, forty-three days after the operation. The graft was little altered in external appearance but somewhat reduced in size, the original length was 6 cm.; when examined the length was 5 cm. Sections of the graft showed that the seminal epithelium had the appearance of dead tissue, though the original structure was recognisable, and there was no sepsis; the graft had evidently not been vascularised. On the other hand, the capsule was thickened and seemed to be alive, though not vascularised. I hope to make more grafting experiments in the future, but since the end of March my attention has been given to experiments on the effect of external temperature on the rat's testes.

Heat Experiments.

Various experiments on the effect of an artificially raised temperature on the mammalian testis have been made by previous investigators. Oslund, in the U.S.A., enclosed the scrotum of a ram in woollen materials and a waterproof covering and found, after a period of 80 days, that the seminal epithelium was disorganised. I found it impossible to apply this method to either rabbit or rat, but have successfully carried out another method which involves no interference with the natural condition of the scrotum by artificial covering. The method is simply to keep the animal in a small water-oven in which the level of the water in the double wall is only 2 or 3 ins. above the floor of the chamber. A mercury gas-regulator is placed in the water and connected with a small flame below the oven. The temperature of the water is kept as constant as possible at 37·5° (which is the rectal temperature of the rat). There is an aperture about 1 in. in diameter in the roof of the oven, and the front is merely closed with a piece of perforated zinc. In this way the exterior of the scrotum is exposed to the temperature of the interior of the rat's abdomen, while at the same

time the head and upper part of the animal are in a lower external temperature. Under these conditions rats have been kept many days without loss of health or appetite and without signs of serious distress or any effects on health after removal from the apparatus.

Experiment 1.—Begun on February 22 and continued till March 16, twenty-three days altogether, but during this time the rat was returned to the animal house every night and during the week-ends, except for the last four days, so that for the greater part of the time it was exposed to the high temperature for only six or seven hours every day. When the rat was killed the vas deferens and epididymis were found to contain abundant actively moving sperms. Prepared sections of the testis showed the condition of normal spermatogenesis in the majority of the tubules, but in a few there was some disorganisation, the lumen being filled with loose detached cells.

Experiment 2.—Begun on May 1. The rat was kept in the apparatus continuously except once, when it escaped, and was found wandering on the floor. It remained well and active, and took food regularly. On May 12 I removed the left testis under chloroform. Prepared sections of this testis showed that in the majority of the tubules the lumen was full of detached cells and *débris*, and the surrounding epithelium disorganised. The peripheral tubules next to the external capsule still showed the normal condition of spermatogenesis. The animal was kept alive for five days after the operation, and was active and feeding well, but as it developed a swelling on the penis it was killed with chloroform. No sepsis was found. In the vas deferens of the remaining testis were abundant sperms without movement and evidently dead. The interior tubules showed signs of recovery and regeneration, but there was no spermatogenesis in any tubules.

Experiment 3.—Begun on June 11 and continued for nine days, when the right testis was removed for examination. The vas contained abundant sperms but all dead and motionless. Sections showed an earlier stage of disorganisation than that seen in the previous experiment.

The chief value of these experiments is that in them no other alteration of the natural conditions is made than to expose the scrotum to a temperature equal to that of the interior of the animal's abdomen, and that the course of disorganisation in the seminal epithelium can be traced in detail. I hope in the future to publish a description of the process. At present I can only call attention to the facts that the normal condition persists longer in the peripheral tubules than in the more internal, and that disorganisation in the individual tubule commences in the internal layers of cells next to the lumen and proceeds centrifugally.

This Report has been drawn up by Mr. Cunningham and approved by the other members of the Committee.

Geography of Tropical Africa.—*Report of Committee* (Mr. J. McFarlane, *Chairman*; Mr. A. G. Ogilvie, *Secretary*; Mr. W. H. Barker, Prof. P. M. Roxby).

The Committee, during the past year, has explored the field of investigation and taken steps for getting into touch with Government Departments and other organisations concerned. They have received some favourable response, and are now prepared to make a start on work along several of the lines suggested in their memorandum prepared on the formation of the Committee and now printed below. Hitherto the only expenses have been those of postage, but the work envisaged for the current year includes the printing of a pamphlet which it is hoped to prepare for issue at the South African Meeting. The Committee is anxious to push forward its work in view of that meeting. They therefore wish to apply for a grant of £25.

The Committee would further draw attention to the resolution of Section E regarding the completion of the War Office Map of Africa (1 : 2,000,000). This map is an essential base map for all work contemplated by this Committee.

In view of the rapid social and economic changes that are taking place in British Tropical African territories, there is a pressing need for systematic study of the native populations. While there is every likelihood that British anthropologists will see

that such study is actively prosecuted from their point of view, it is most unlikely that adequate work will be put into the relationship of the native to the land he lives in unless the geographers of this country insist that much greater stress be laid on this geographical question than has hitherto been the case.

1. In view of the fact that it is desirable to have as many distributions both physical, biological and human plotted upon the maps of British Tropical African territories, it is necessary to know the relative reliability of the existing map in each of its parts. The Geographical Section, General Staff, might be asked to furnish a statement upon this subject. Preferably the statement should be supplemented, if possible, by making accessible for inspection sheets of the map of Africa (1 : 2,000,000) upon which areas are marked to show the degree of accuracy which the compilation represents.

2. The preparation of systematic geographical bibliographies of the various territories is desirable, with index maps to show the areas to which data refer. This will require the undivided attention of a considerable staff, and would have to be done in London, where alone the references can be traced.

3. Arising out of (2) it would be possible to classify knowledge according to its character, and the fields of various sciences whose data are useful in geographical research of a physical character—geology, climate, vegetation, fauna. But, since each of these subjects falls within the province of workers other than geographers, it was felt that the pressing need for research by geographers lies in the field of human geography, and that studies should be energetically pushed forward in this subject in order that the attention of all concerned with the future welfare of the inhabitants may be directed to the all-important fact that African peoples cannot adequately be studied or treated except as in relation to the land they inhabit.

Work done in accumulating and disseminating data upon the human geography of Tropical Africa will serve two purposes. It will give an opportunity to those concerned with and familiar with conditions in one territory to learn the conditions prevailing in other territories, and to make practical use of the comparison. It will further be of the greatest service to people in Great Britain and elsewhere who are engaged in teaching the geography of Tropical Africa. For it will enable them for the first time to spread an accurate knowledge of the essentials of native life associated with the different types of environment.

Data upon the human geography can probably be most rapidly accumulated by seeking the co-operation of two types of people : (*a*) those at home who are familiar with the literature of Africa, and who might be asked to make extracts of pertinent matter from literature at their disposal ; (*b*) persons who as residents in Africa are in a position to obtain new data ; and this class is by far the more important, since it is believed that existing literature (mainly anthropological) contains relatively little that is pertinent.

It was therefore felt that a memorandum should be prepared and circulated as widely as possible in Tropical Africa with a view to interesting residents in this matter. The classes of people who, it is hoped, may be expected to respond and to yield an ever-increasing stream of information include (*a*) Government officials, (*b*) missionaries, (*c*) planters, and other private individuals who may be discovered.

The memorandum should contain (1) a suitable explanation of the reasons why this information is desired ; (2) a reprint of excerpts of the best account yet published of the human geography of an African region ; (3) a list of desiderata, and an exhortation to furnish not merely statements in words, but also maps illustrating the statements.

If possible the memorandum should go out with the approval and recommendation of the Colonial Office and of the missionary organisations. And, since the work of collecting the data can probably be most effectively done by the district officers of the Governments, it is desirable that an effort be made by the Colonial Office to procure sufficient leisure for the proper officers in order that they may perform this valuable service. The information desired falls into two categories :—

The first group of data is sought with a view to the preparation of a uniform map of the distribution of population density in British Tropical Africa ; and this information should be supplied by the Government Authorities.

(*a*) The latest census figures, given for the smallest possible administrative divisions ; (*b*) A map with these divisions marked (where they do not appear on a published and accessible map) ; (*c*) Notes to supplement the above as to the distribution and density within these divisions and the apparent causes of such differences

of density.[1] The proposal is that then a map may be prepared in Britain on the 1 : 2,000,000 scale, and that the sheets be sent in MS. to the respective Governments for suggestion as to correction.

The second group of data relates to the life of the people in relation to the land and the environment generally. It is hoped that individual residents will undertake to furnish information on the following points :—

For the area to be reported on by each contributor.

1. A map showing tribal divisions.
2. An account of the habitations and life of the people thus :—

(*a*) Do they live in towns, villages or in disseminated dwellings, and can any cause be assigned to explain ?

(*b*) What type of situation do towns, villages, etc., occupy, *e.g.* valleys, plateaus, slopes, forest, grass, etc. ? Any reason for the choice, *e.g.* water supply, drainage, fly, etc. ?

(*c*) Is there a typical town or village plan ? (Supply sketch of it in relation to site.)

(*d*) Of what are houses constructed ?

(*e*) How long do villages remain in one place ?

(*f*) When moved, how far ? Where ? Why ?

(*g*) What is means of livelihood of natives ? (i) Native agriculture (what crops ?), (ii) labour on plantations, porterage (how far away and where and for what reason ?), (iii) pastoral.

(*h*) In relation to (*g*) what area is used by natives of a village ? How frequently are cultivation patches or flocks moved ? How far, and where ?

(*i*) To what extent do natives cut forest, burn grass and bush, and for what purposes ?

(*j*) What depredations of wild animals take place, *e.g.* elephants, zebras, etc. ; fly, mosquitoes (diseases) ; what areas ?

(*k*) An account of seasonal activities month by month in relation to climate, state of the rivers, &c. Do these involve separation of families ?

(*l*) In dry season or arid districts—water supply and uses of water.

(*m*) Seasonal migrations, extent and reasons of these.

(*n*) Permanent or semi-permanent migrations ; influence of roads and railways on these.

(*o*) Nature of new occupations of the natives and the manner in which it affects any or all of the above subjects.

(*p*) Methods of transport.

(*q*) *In relation to the above*—a brief account of : the political organisation of the people, where such exists or has existed ; the organisations of the family group, the status of men and women, with special attention to the work of both sexes ; the cultural attainments of the people ; their crafts.

In answer to the above questions, the fullest possible explanations would be welcome, and in regard to any point comparisons with adjoining districts, together with the probable reasons for any differences noted.

[1] The local contributors might also be asked for information on this point.

Bronze Age Implements.—*Report of Committee* (Prof. J. L. Myres, *Chairman* ; Mr. H. J. E. Peake, *Secretary* ; Mr. Leslie Armstrong, Mr. H. Balfour, Prof. T. H. Bryce, Mr. L. H. Dudley Buxton, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Dr. Cyril Fox, Mr. G. A. Garfitt) *appointed to report on the distribution thereof.*

The catalogue now contains upwards of 12,000 cards. As far as is known, all the specimens in the museums and private collections in the Channel Islands and the Isle of Man have been included, a considerable number from Scotland and Ireland, while of those in the museums of England and Wales there remain only the late hoards in the British Museum and the Evans Collection in the Ashmolean, besides a few in private hands. Fresh specimens are, however, turning up almost monthly,

and these are usually catalogued as soon as they are brought to our notice. Since the services of our regular draughtsman have been dispensed with, the Committee have entrusted the preparation of the cards to Miss L. Chitty.

It has been found impossible this year to obtain the assistance of a voluntary worker to sketch the remaining specimens in the British Museum, while the Evans Collection was not available until the beginning of this year. Owing to the absence of the Secretary abroad no arrangements were made to draw and measure these, but quite recently a lady has been found who is prepared to undertake this work. As she will require remuneration for her services, the Committee ask to be allowed to retain their unexpended balance, which amounts to £37 3*s.* 4*d.*

Early in the year the Society of Antiquaries placed at the disposal of the Committee the use of a small room in which to place their catalogue, and the Committee have taken this opportunity of purchasing the necessary cabinets and cupboards in which to store the cards, the original sketches and all correspondence relating to the work, as well as a stock of cards to meet their needs in the immediate future.

Kent's Cavern, Torquay.—*Report of Committee appointed to co-operate with the Torquay Natural History Society in investigating Kent's Cavern* (Sir A. Keith, *Chairman*; Prof. J. L. Myres, *Secretary*; Mr. G. A. Garfitt, Prof. W. J. Sollas, Mr. Mark L. Sykes).

A. Operations, *November* 1927–*June* 1928.

Bad weather conditions have seriously interfered with the excavations this season. For some weeks after snow fell at Christmas sorting was impossible, and the old workings were perforce temporarily abandoned. It was not until March that work could be resumed in the Vestibule, and the deposits in the N.E. Gallery were not really fit to sort at the end of May. Owing to these conditions, and the relatively barren nature of the lower deposits in the Vestibule, we have little to report this year of scientific interest.

The N.E. Gallery.—No definite results were obtained here during the autumn campaign, and no flints were found.

The Vestibule.—In this chamber the trench was eventually taken down to rock bottom at just over 23 feet, where water-worn rocks were revealed descending into a fissure too narrow for work. Scanty remains of the usual cave fauna continued to the bottom, and there has been no change in the character of the infilling. Not a single fragment of flint or worked bone has been found below 15 feet. Very large fallen blocks of limestone rest here on a base of cave earth and shattered rock, which would require much labour to remove. But it does not appear likely that there would be anything to gain in doing so.

The Gallery.—While waiting for the deposits in the old workings to dry, it was decided to sound this small chamber, which opens out of the W. wall of the Great Chamber. Here Pengelly had revealed an interesting sequence of deposits in 1866 :—

5. Stalagmite floor	to 3 feet
4. Void space	6 inches to 4 feet
3. Granular Stalagmite	3 inches to 2 feet
2. Cave Earth	2 feet, incorporating broken Stalagmite
1. Sandy Grit	2 feet or more

and had reported a few bones, one of them burnt, from the basal deposit of sandy grit. Elsewhere in the S.W. chamber Pengelly had reported a similar sandy grit in a clearer sequence :—

4. Granular Stalagmite
3. Crystalline Stalagmite
2. Breccia, incorporating broken slabs of Stalagmite
1. Sandy Grit

where the cave earth had thinned out to zero, but all the deposits lay in their natural position. It seems, therefore, that although in the Gallery the upper and lower stalagmitic floors lay in inverted positions, the sandy grit is *in situ* at the base, and may represent deposits as old as, or more probably even older than, the Breccia, and once divided from the latter by a formerly existing stalagmitic floor.

It was, therefore, in the hope of finding human artefacts, at least as old as the Chellean tools found in the Breccia, that our attention was turned to the Gallery. As a result we have to report the following sequence of deposits :—

3. Tough Red or Yellow Clay	about 15 inches
2. Finely Laminated Buff Clay . . .	about 10 inches
1. Sandy Loam	about 2 feet

The geological character of all three deposits, which are not always very distinct, is the same, and represents a wash of the grits and their incorporated slates, from the Lincombe Hill which rises above the limestone plateau, and which represents the upper division of the Lower Devonian rocks in the Torquay area. The deposits are 'flooded' with minute particles of these slates, and well-rounded pebbles of the grit occur, occasionally in the two upper levels, and frequently in the sandy loam. On the other hand, fragments of limestone from the walls or roof are practically absent. The phenomena therefore seem to point to a period when only quiet waters entered the cave, and indeed the finely laminated and tough clays may well have been laid down under standing water. So far as is known these are the only stratified deposits in Kent's Cavern.

Nothing of human manufacture has as yet come to light. Nevertheless, in view of the possibility that we have here the oldest known deposit in the Cavern, we think that this small chamber should be cleared to rock bottom, since it is possible that a more prolific stratum may lie below the almost barren clays and sand.

In the autumn of 1927 Prof. W. J. Sollas, F.R.S., very kindly sent a small series of twenty-two flints found in the Vestibule to Paris for classification by Prof. the Abbé Breuil. Of these three were returned as 'atypical' and four more as undetermined Upper Palæolithic. Of the remaining fifteen there were :—

Five possibly Upper Aurignacian (two simple blades, a blade with lateral hollow scraper, and two end scrapers).
One either Middle or Upper Aurignacian (end scraper).
Five probably Upper Aurignacian (four blades and a lateral end scraper).
Two certainly Upper Aurignacian (two lateral gravers).
One either late Middle or Upper Aurignacian (blade).
One probably late Middle Aurignacian (blade).

Excluding the two lateral gravers, the series does not appear to be very typical. But if the general *facies* may be taken to be Upper Aurignacian, we are faced by the position that this period is represented in the cave earth at 5 feet to 8 feet below the upper stalagmite, while a small series of Middle Aurignacian implements has been identified by Miss Garrod from the 3-foot to 4-foot level, and in the same chamber. It seems clear, then, that some redeposition of the cave earth has taken place.

B. *Suggestions for Further Work.*

The original objective in view, in driving a trench along the N. wall of the Vestibule, was to seek for lower and older occupation floors beneath the position of the Black Band. Rock bottom has now been reached, with a negative result. It is now necessary to decide on the next position to attack, and this is no easy matter in so large a cave. Miss Garrod has pointed out that the Aurignacian, Solutrian, and Mousterian of Kent's Hole localise respectively in the Vestibule, the South Sally Port, and the Great Chamber. The last is, unfortunately, a much-used tourists' track, and over part of its area Pengelly had already exposed rock bottom. He found Mousterian implements in each level of the cave earth here, but at the same vertical level as flints of Upper Palæolithic Age. The suggestion that a Mousterian floor lies at the base of the cave earth in this Chamber does not, therefore, appear to be promising. It seems more likely that the same phenomenon of redeposition of the cave earth, presumably in Magdalenian times, seen in the Vestibule, has been repeated here.

The South Sally Port is even less promising. Pengelly reports honeycombing, of the upper deposits at least, by burrowing animals, and a basal deposit, archæologically barren, of mixed sandy grit and cave earth.

At this point we are over 100 feet from the entrance, and all experience seems to be against hope of finding occupation sites further into the interior of the Cavern. We return to the entrances, but they are unfortunately closed to us. Immediately outside the one the ground is covered by the machinery supplying electric light to the cave. The other opens on a public right of way, and is the only means by which tourists enter to view the interior.

The plateau is above, under houses and private gardens, and here again excavation is impossible. There remains a shelf or platform, running below the escarpment at a level varying from 15 feet to 30 feet above the entrances, from 30 feet to 40 feet broad, and extending on both sides of the entrances. We have obtained permission to sink a series of pits here during the remainder of this summer and autumn in the hope of finding the remains of hearths and occupation sites.

We desire to add the names of the Rev. H. B. Hunt, M.A., and Mr. J. J. Judge to those mentioned in previous reports as ready helpers in the work.

(Signed) F. Beynon, H. G. Dowie, A. H. Ogilvie.

Egyptian Peasantry.—*Report of Committee* (Prof. J. L. Myres, *Chairman*; Mr. L. H. D. Buxton, *Secretary*; Mr. H. Balfour, Mr. E. N. Fallaize, Capt. M. W. Hilton Simpson, Prof. H. J. Rose) *appointed to investigate the Culture of the Peasant Population of Modern Egypt.*

The Committee reports that Miss Winifred Blackman, whose inquiries among the peasant population of Egypt have now been continued since 1922, with the help of grants from the Royal Society, the Percy Sladen Trustees, The Wellcome Medical Museum and other sources, has remained in Egypt throughout the past twelve months, and has therefore fulfilled the condition on which the Association's grant at the Leeds meeting was made. The grant has accordingly been paid over to her.

During the past year Miss Blackman has lived in the neighbourhood of Cairo, and has succeeded in collecting much folklore from her native acquaintances. Samples of drugs, charms and other objects used in native medicine have been sent to the Wellcome Medical Museum, 54a Wigmore Street, London, W. 1, in return for the Museum's subsidy, and are now arranged for exhibition there. The Committee recommends that ethnographical specimens collected with the Association's grant be offered to the Pitt Rivers Museum at Oxford.

Miss Blackman's book on *The Fellahin of Upper Egypt* was published in the autumn of 1927 by Messrs. G. G. Harrap & Co., London, and she hopes soon to complete her monograph on the *Cults of Sheikhs and Saints in Egypt.*

Sumerian Copper.—*Report of Committee* (Mr. H. J. E. Peake, *Chairman*; Mr. G. A. Garfitt, *Secretary*; Mr. H. Balfour, Mr. L. H. Dudley Buxton, Prof. Gordon Childe, Prof. C. H. Desch, Prof. H. J. Fleure, Prof. S. Langdon, Mr. E. Mackay, Sir Flinders Petrie, Mr. C. Leonard Woolley) *appointed to report on the probable source of the supply of copper used by the Sumerians.*

The Secretary has procured a large number of samples of ore from Anatolia. Persia, Arabia and Egypt, and many specimens of early metal found in Mesopotamia, Persia, Egypt and India. These have been submitted for analysis to Prof. C. H. Desch and Prof. C. O. Bannister. A report on some of these from Prof. Desch is appended.

Report on the Metallurgical Examination of Specimens for the Sumerian Committee of the British Association. By Prof. C. H. Desch, F.R.S.

A principal object of the work of the committee has been to determine the source of the copper used by the Sumerians. The most promising method of attaining that object was to determine the nature of the impurities usually contained in the early copper and bronze, with the possibility that some impurity might prove to be sufficiently characteristic to indicate the ore from which the copper had been obtained. After examining a large amount of material it was found that nickel was frequently present in the earliest specimens of copper and also of bronze. Most of the other impurities are common to many ores, but nickel is by no means an invariable constituent of copper ores, and it is very suitable for the purpose. The modern method of estimating nickel in a chemical analysis is by precipitation with dimethylglyoxime, which gives a perfect quantitative separation from other metals, whilst the colour of the precipitate is so characteristic that there is no possibility of confusion with other impurities. In the course of the work it became advisable to examine the older published analyses of ancient copper and bronze objects. The most important work on this subject is 'Die Bronzen und Kupferlegirungen der alten und ältesten Völker,' by Ernst Freiherr von Bibra, published by Ferdinand Enke in Erlangen in 1869. This work contains a critical examination of the composition of ancient copper and bronze, with a very large number of analyses. The analyses of such objects found in more recent books are very frequently derived from the work of von Bibra, although they may be attributed to quite other authorities, having been repeatedly copied by other writers at second or third hand. As many of the analyses show the presence of nickel, and the modern method of estimating that element was not devised until much later, it became necessary to examine the chemical methods used by von Bibra, with a view to determining how far they may be relied on. This work was kindly undertaken by Dr. F. Ibbotson, who carried through a number of analyses, proving that von Bibra's method for the estimation of nickel, depending on the precipitation of the ferrocyanide and its separation from other ferrocyanides by means of alkali, is fairly trustworthy. It is liable under certain conditions to give rather high results, but it will not indicate the presence of nickel in an alloy which does not contain that metal. This is satisfactory, as it enables us to make use of a number of old analyses.

Some of the early copper specimens are of remarkable purity. It has been suggested that this is due to native copper having been used, but such metal is not invariably pure, and it is very likely that the pure metal has been obtained by smelting malachite, a mineral of such characteristic appearance that it would be easily recognised by the early metallurgists, and often of high purity. Two specimens of native copper have been examined in the course of this investigation, the analyses, after deducting sand and other mechanically mixed impurities, being as follows :—

	Native copper from Angora. per cent.	Native copper from Arghana. per cent.
Copper	99·83	97·08
Tin	trace	0·27
Iron	0·17	2·13
Nickel	—	0·03
Sulphur	—	0·49

No lead, arsenic, antimony or bismuth.

Only the first of these specimens can be described as of exceptionally high purity. On the other hand, drillings received by the writer, taken from an axe found in the lower deposits of Susa, and now in the Louvre, showed on analysis no more than a faint trace of nickel, all other impurities being absent, so that the object may be described as of very pure copper. A copper chisel of the early Dynastic period of Egypt, analysed by Prof. C. O. Bannister, gave the following figures :—

	per cent.
Copper	93·21
Silver	2·51
Gold	4·14
Lead	0·05
Arsenic	0·06

Iron and tin, traces.

The composition of this specimen, with the high proportion of silver and gold, suggests that it is composed of native metal.

The search for copper ores containing nickel, which might have been made use of by the Sumerians, proved to be a long one. Ores from Persia, the neighbourhood of the Black Sea and the Sea of Marmora, Cyprus, various parts of Egypt and Sinai, were all found to be free from nickel, and it was only recently that an ore, found accompanied by slag at Jabal al Ma'adan in Wadi Ahin, inland from Sohar, in the State of Oman, proved to contain nickel. The ore was only in the form of thin veins, much mixed with other minerals, so that the percentage of copper was small, but that of nickel was, relatively to the copper, very high.

	Ore L.GM 595.
	per cent.
Copper	1·0
Nickel	0·19

The two slags which accompanied it contained 1·50 and 4·30 per cent. of copper respectively but no nickel, which is in accordance with the probable smelting practice.

Three specimens from the first grave at Ur, dated about 3500 B.C., although of such early date were found on analysis to consist of tin bronze, with nickel as a characteristic impurity. In the analyses of metal which follow, the figures have been recalculated to give the probable composition of the unoxidised metal, oxygen, carbon dioxide, and such mechanically admixed impurities as sand or clay, being deducted, so that a fair comparison may be made.

	A.	B.	C.
	per cent.	per cent.	per cent.
Copper	84·18	85·13	85·01
Tin	12·00	11·78	14·52
Lead	1·62	1·13	0·47
Nickel	2·20	0·25	trace
Iron	—	1·71	—

Six specimens from the 1928 excavations at Kish also contained nickel, although in smaller quantities :—

	*156693.	*156835.	*156688.	*156796.	*156700.	Unnumbered.
	1581.		2442.		2313.	
Copper . . .	57·12	67·46	68·40	80·30	64·42	78·12
Tin . . .	8·21	8·60	10·70	2·52	5·33	5·17
Nickel . . .	0·05	0·07	0·17	0·09	0·02	0·005

Owing to lack of time a complete analysis of these specimens has not been made. Assuming that the purity is similar to that of the metals in the above table, the proportions of tin and nickel would be approximately as follows :—

	*156693. 1581.	*156835	*156688. 2442.	*156796.	*156700. 2313.	Unnumbered.
Tin	12·2	11·0	13·2	3·0	7·4	6·1
Nickel	0·07	0·09	0·21	0·10	0·03	0·006

suggesting that the ores used were similar to those of the metals from Ur.

The following analyses of metals received from Kish in 1925 may be added :—

	Copper from Mound A. 3000 B.C. per cent.	Bronze from Mound W. Nebuchadnezzar period. per cent.
Copper	94·01	88·16
Tin	0·43	4·65
Iron	1·31	6·16
Lead	0·58	0·15
Nickel	3·34	trace
Sulphur	0·17	0·42
Gold	trace	—

The following analyses have also been made :—

	Lion Frieze at Tel-el-Obeid. per cent.	Nail from Tel-el-Obeid (Brit. Museum). per cent.	Nail from Iraq, 2000 B.C. (from Miss Bell). per cent.
Copper	98·81	99·21	88·60
Tin	trace	0·16	9·77
Nickel	0·12	0·23	—
Iron	0·98	0·25	0·28
Lead	—	—	0·68
Sulphur	0·09	0·12	0·17
Arsenic	—	0·02	trace

None of these metals has been found to contain antimony.

Five specimens of bronze, probably of about 1200 B.C., were obtained by Sir Flinders Petrie from tumuli in Bahrein Island.

	Burial 5	Burial 6	Tumulus 3	Tomb 7	Tomb 8
Copper	89·07	87·76	94·69	77·53	82·16
Tin	9·60	11·70	3·18	19·27	16·57
Nickel	—	—	0·27	0·52	—
Iron	0·53	0·54	0·44	0·94	0·75
Lead	0·27	—	0·47	1·40	trace
Sulphur	0·53	trace	0·95	0·34	0·52

Such irregularities in the proportions of tin and sulphur point to a less developed art of smelting than in some of the other groups of specimens analysed. A high proportion of sulphur is evidence of imperfect smelting, whilst the tin varies from a quantity insufficient to harden the bronze effectually to one so high as to make the metal far too brittle.

Ores from Sinai were examined and found not to contain nickel, and for comparison with them an ingot of copper from Bir Nasb, Sinai, was analysed :—

Copper.	Tin.	Nickel.	Iron.	Lead.	Sulphur.	Arsenic.
93·01	—	—	5·91	—	1·00	0·08

Certain Egyptian objects have been analysed, the most interesting of which is the sheet metal of the statue of Pepy I, in the Cairo Museum :—

Copper.	Tin.	Nickel.	Iron.	Lead.	Sulphur.	Arsenic.
98·20	—	1·06	0·74	—	0·01	—

the high percentage of nickel being remarkable.

Some fragments received from the Ashmolean Museum were too small for an analysis, and it was only possible to test them spectroscopically for the presence of unusual metals, and in some instances to estimate the tin content. None of these contained either gold or nickel.

Tanged pike-point or spear-point. 1914/206. Tell Kara Hassan. Pure copper.
Flat celt. 1914/525. Serrin. No tin, traces of iron and arsenic.
Bracelet. 1914. Kara Kuzak. Tin 5·25 per cent. Traces of iron and arsenic.
Knife. 1914/175. Hamman. A little tin, traces of iron and arsenic.
Head of pin. 1914/177H. Tin 2·76 per cent., otherwise spectroscopically pure copper.

The specimens from Mohenjo-Daro have not been completed in time for this report, but an analysis of one Indian specimen may be given, having been obtained by Col. F. J. Richards from Odugattur in North Arcot.

Copper.	Tin.	Nickel.	Iron.	
84·10	trace	0·25	15·75	Other metals absent.

Von Bibra records the presence of nickel in three objects found by Layard in the N.W. Palace of Nineveh, the percentages being 0·18, 0·30 and 0·20 respectively, or of the same order as those found in the present work. J. Sibelien (Ancient Egypt, March 1924) found 0·28 per cent. of nickel in a Sumerian statuette, supposed to be of date 3000 B.C., and 0·43 per cent. of nickel in a copper adze of the First Egyptian Dynasty. Ancient bronze from the Transvaal has been found to contain as much as 3 per cent. of nickel. In this instance the copper ore is malachite in a quartz gangue, and it is accompanied by a green nickel arsenate, anabergite, which might easily be mistaken for malachite, thus offering a possible explanation for the presence of nickel.

In the course of the examination of copper and bronze objects a few other metallic specimens have also been analysed, the results being collected in the following table :—

	Silver finger ring. Early Sumerian. Mound A. Kish.	Silver fragments. Nebuchadnezzar period. Mound W. Kish.	Lead. Early Sumerian. Mound A. Kish.
	per cent.	per cent.	per cent.
Silver	94·86	92·98	trace
Gold	0·29	1·57	—
Copper . . .	4·85	4·23	—
Tin	—	—	1·30
Lead	—	1·22	98·29
Iron	—	—	0·41

The silver was in all probability native metal, whilst the lead had been smelted from a simple ore.

Iron. Special interest attaches to the examination of iron objects found in early deposits, on account of the different opinions which have been expressed as to the date at which the smelting of iron began. It is likely that such objects of iron as are found in the most ancient deposits have not been smelted from an ore, but have been made from meteorites, either by chipping and hammering while cold, or by heating to a forging temperature and then hammering to shape. As most meteorites contain nickel, a chemical analysis will usually serve to determine this point, even when the specimen is too much rusted to allow of microscopical examination.

A single iron object was found by Mr. Woolley in the first grave at Ur. An analysis of the oxidised material, assuming no other metals to be present, gave the composition iron 89·1 per cent., nickel 10·9 per cent., in perfect accordance with a meteoritic origin. For comparison Sir Flinders Petrie was able to procure one of the beads from Gerzeh in Egypt, which have often been cited as evidence of an

early knowledge of iron smelting. An analysis showed the metal to consist of iron 92·50 per cent. and nickel 7·50 per cent., again proving a meteoritic origin. The blade of iron found in the Great Pyramid, now in the British Museum, does not contain nickel, having been examined in the museum laboratory, but it appears very doubtful whether this object really has the age assigned to it.

I have to thank Mr. F. Orme, Dr. F. Ibbotson and Mr. E. Gregory for many of the analyses contained in the present report. Many ores have been completely analysed, but as these did not prove to contain the elements for which special search was being made, it does not seem necessary to reproduce them, although they have been circulated to members of the committee.

The Place of Normal Psychology in the Medical Curriculum.

—Final Report of Committee (Dr. W. Brown, *Chairman*; Dr. R. D. Gillespie, *Secretary*; Dr. C. H. Bond, Prof. E. P. Cathcart, Dr. H. Devine, Dr. J. A. Hadfield, Dr. Bernard Hart, Dr. D. K. Henderson, Dr. J. R. Lord, Dr. C. S. Myers, Prof. T. H. Pear, Prof. G. M. Robertson, Dr. T. A. Ross).

A questionnaire was circulated to all the Medical Schools in the British Isles and in the Dominions, two questions being asked :—

(*a*) What facilities were offered to medical students for acquiring a knowledge of normal psychology ?

(*b*) Whether an optional or a compulsory course was favoured ?

Replies were received from all but one or two schools.

The answers to question (*a*) showed that the facilities in different schools varied greatly, from none at all to rather elaborate courses.

Thirteen schools in the British Isles offer no facilities at all; eight offer optional courses, and five give compulsory ones. The majority of schools in the Dominions offer courses, sometimes apparently very extensive.

When a course in normal psychology is offered, the tendency is to place it in the pre-clinical or early clinical years.

The usual facilities offered consist in a course of lectures in normal psychology. In some cases a course in experimental psychology is also given.

The majority of the opinions given (mostly personal opinions of the Deans of the respective schools) favour the provision of instruction in normal psychology. The majority of such opinions (twelve out of sixteen replies to query (*b*)) favoured an optional course; but in four schools at home and in five out of the six Dominion schools who replied, instruction is already compulsory.

Resolved.

That it is the opinion of the Committee, after examining the existing arrangements, that facilities should be given in every Medical School for instruction in normal psychology.

This instruction should be given in the pre-clinical years (preferably the second).

It should in the meantime consist in a course of not less than ten and not more than twenty lectures; and (whenever possible) of a course in experimental psychology of about ten two-hour meetings.

The course should be compulsory.

The instruction should throughout have special reference to medico-psychological facts and problems, so as to give a working basis for subsequent lectures in morbid psychology (which should be considered a necessary part of the general instruction in psychiatry).

The findings and resolutions of the Committee be circulated to the Medical Schools who have replied.

The Effect of Ultra-violet Light on Plants.—*Report of Committee* (Prof. W. Neilson Jones, *Chairman*; Dr. E. M. Delf, *Secretary*; Prof. V. H. Blackman, F.R.S.). *Drawn up by the Secretary.*

Experiments have been carried out under my direction from July 1927 to March 1928 at the experimental greenhouse at Bedford College, by the courtesy of Prof. Neilson Jones. In June the apparatus was removed to Westfield College, but owing to the alterations in the electrical supply which its installation there necessitated, its use has been considerably delayed.

Plants of *Voandzeia subterranea* were subjected to short daily irradiations from a Hewittic mercury vapour lamp, transmitted through selective glass screens. The time of exposure under each was adjusted as far as possible so that the amount of energy received in unit time under each was about equal, as judged by the visual effect on standardised lithopone paint. An anatomical investigation of these plants has been made. It is hoped that these experiments may be repeated and confirmed, using a thermopile and galvanometer to measure the incident energy more exactly.

Previous experiments have shown that plant surfaces exposed to the unscreened radiations frequently become browned, the browned areas corresponding to regions where the epidermal cells are killed and have collapsed. The epidermal collapse has been investigated in more detail, using a variety of plants. A short account of these epidermal experiments is being read before Section K of the British Association by Miss M. T. Martin, B.Sc.

The accounts show an unexpended balance of £20 9*s*. 9*d*. on the last year's grant. This is owing to the unexpected delays in the transference and installation of the mercury vapour lamp at Westfield College. The cost of an appropriate thermopile and galvanometer will be from £50 to £60, and it is hoped that the committee may be continued in office for another year, with power to use the balance in part payment of these instruments.

Science in School Certificate Examinations.—*Report of Committee* (Sir Richard Gregory (*Chairman*), Mr. H. W. Cousins, Mr. G. D. Dunkerley (*Secretaries*), Mr. D. Berridge, Mr. C. E. Browne, Dr. Lilian Clarke, Mr. G. F. Daniell, Mr. J. L. Holland, Mr. O. J. R. Howarth, Mr. J. Wickham Murray, Dr. T. P. Nunn, Mr. E. R. Thomas, Miss Von Wyss, Mrs. Gordon Wilson), *appointed to enquire into the nature and scope of the science syllabuses prescribed or accepted by examining authorities in England for the First and Second School Certificate Examinations, and to make recommendations relating to them; particularly in regard to their relation to Matriculation and other University Entrance Examinations and their suitability as essential subjects of instruction in a rightly balanced scheme of education designed to create an intelligent interest in the realm of nature and in scientific aspects of everyday life.*

Introduction.

The establishment of School or Leaving Certificates upon an organised and national basis was recommended by the Acland Report on Examinations in Secondary Schools, published in 1912. Five years later, at the suggestion of the Right Hon. H. A. L. Fisher, then Minister of Education, the examining bodies of Universities appointed representatives to an Examinations Council to consider and report upon (1) the Co-ordination of School Examinations, (2) the Relationship between School Examinations and University Entrance Examinations.

The result was that in March, 1918, the Board of Education issued a list of examinations recognised for the award of First and Second (or School and Higher) Certificates. The examinations are now conducted by eight approved Universities or other authority in England and Wales, and candidates must select subjects from each of three or four groups, one of which includes science. The First School Examination is taken at about sixteen years of age, and is of the general standard of the Senior Local Examinations of Oxford and Cambridge, or London Matriculation; the Second or Higher Examination is taken about two years later and is roughly of the standard of an Intermediate Examination for a degree.

In instituting the First School Examination, the intention was that it should represent the contents of a general education up to sixteen years of age and should include English subjects, languages other than English, mathematics and science, together with drawing, music, handwork and related subjects. There was to be no specialisation up to this stage, either on the literary or on the scientific side, and all pupils in secondary schools were intended to be presented for the examination when they reached the appropriate form in their schools.

In the science group of subjects, however, little serious attempt has been made to devise a course of instruction suitable for all pupils. There are syllabuses of mechanics and hydrostatics, light and heat, electricity and magnetism, chemistry, botany, natural history, and many other

separate divisions of science, any one of which may be included in the curriculum for the purposes of the First Examination, but it can scarcely be suggested that a single subject of this kind represents what should be science for all in a general education, or is likely to inspire wide interest in the realm of Nature or in everyday aspects of scientific knowledge and use.

It was to obtain particulars as to the actual position of science in School Certificate Examinations, as indicated by the subjects in which candidates presented themselves, and with special reference to the desirability of a general science course for pupils who do not propose to proceed to Universities or specialise in science, that this Committee was appointed. The statistics included in this Report represent the relative attention given to various scientific subjects in secondary schools, and it will be seen that these are almost entirely certain branches of physics, or chemistry or botany. General science occupies a low place in comparison, and biological subjects other than botany are deplorably neglected. The Committee hopes that this survey will serve to direct attention to the present unsatisfactory condition of things in regard to these subjects, and that efforts will be made by both school and examining authorities to widen the scope of science teaching and bring it in closer contact with living things as well as with the many natural phenomena of our changeful earth and man's relation to them.

1. School Certificate Examinations.

First School Examination.

The most important purposes of a school examination are two: (i) to ascertain and record the progress and attainments of individual pupils, and (ii) to test (so far as a direct test is applicable) the quality of the instruction given in the several subjects included in the school's curriculum. This statement applies equally to domestic examinations conducted entirely by the head and assistant teachers in a school and to examinations conducted or supervised by an external authority. An examination of the latter kind may fulfil other important purposes: (iii) the degree of success attained in it by an individual examinee may serve as an index of ability and attainments, useful both as a guarantee of suitability for certain types of employment and as a test of fitness for further education, academic or professional; (iv) the performance in the examination of the pupils as a whole may afford some measure of the confidence which parents and the educational authorities may rightly feel in the soundness of the aims and work of a school, and (v) the syllabuses prescribed for the examination, presumably by experts whose views are authoritative, may have a valuable influence upon the school's curricula and methods of teaching. The last-mentioned point is the one to be taken up in this section of our report.

There is no question that during the latter part of the nineteenth century, public examinations—of which those of the College of Preceptors, the Local Examinations of the Universities of Oxford and Cambridge, the London Matriculation Examination, and the examinations of the Science

and Art Department were the most influential—played an essential part in the renascence of secondary education for boys and its virtual creation for girls. At a time when secondary schools were greatly isolated, when inspection was inadequate or non-existent, and when teachers went to their posts without any professional preparation for their work, these examinations performed a very valuable service in defining curricula and setting up standards against which the schools could measure their achievements. In the rapid multiplication of secondary schools brought about by the Education Act of 1902, public examinations continued to perform that service, and performed it still more effectually when the present scheme of approved First School Examinations brought a degree of order and unity into a field where there had grown up a distracting state of chaos. Nevertheless, there are certain defects inherent in a universal system of external examinations, and the improvement in secondary schools which the English system has done so much to foster, has itself brought those defects into prominence and occasioned a widespread demand for their removal.

The fundamental trouble is that an external examination, especially one intended to be taken in a large number of schools, almost necessarily contravenes the basic principle that examinations should follow and be adapted to the teaching given and not dictate its form and range. While there are, as we have admitted, circumstances in which the inversion of this natural relation may be tolerable and even beneficial, it is bound in the long run to be harmful. It tends (as an experienced critic has said) to 'cramp the style' of schools in which circumstances favour good and original teaching, and it encourages a wasteful misdirection of effort where conditions are difficult. In short, the best possible external examination could be adjusted only clumsily to the widely varying character of the schools in a large area, and would be bound to influence prejudicially the education of many individual pupils.

The present First School Examination is thought by many competent judges to be seriously defective in both these ways. It has, for instance, been pointed out by the Association of Headmistresses, in a memorandum submitted to the Board of Education in March, 1927, that although the examination is intended to test the successful completion of a general secondary education, large numbers of pupils in most schools never take it, and that if the purpose of the examination is to test the average pupil from the average school at about the age of sixteen years, it does not fulfil its purpose. The memorandum included recommendations for widening the subjects of the examination, for the simplification of the questions and for greater opportunities for practical work. It appears clear from the foregoing that the School Certificate Examination should be so amended as to fit the changed conditions, or, if this be impossible, that the School Certificate in its present form should cease to be the normal objective of the average boy or girl. There can be little doubt that among the factors which have produced this unsatisfactory situation two have special importance. The first is that, in spite of a liberal choice of 'options,' the scheme of the examination presupposes, and accordingly imposes on the schools, a type of education which fails to stimulate the intellectual energies of many boys and girls whose ability is not of the

academic type. The second is the related fact that a curriculum planned to lead up to the examination often seems to a pupil to have little or no connection with the needs of any occupation he is likely to follow ; and in many secondary schools the number of the pupils whose school work is affected adversely by this kind of observation is very considerable. Their silent discontent deserves attention not only on its own account, but also because it corresponds with a suspicion among parents, employers, and those engaged in public administration that secondary schools have not yet adjusted themselves to the immense social, economic, industrial and scientific developments of recent years ; in other words, that although they now draw their pupils from a wide area of the adolescent population they still cling to the academic paths that lead directly only to the university and the more learned professions.

These considerations and criticisms point to important modifications of the way in which the First School Examination is administered. It is true that provision is sometimes made whereby a school may substitute its own syllabus in a particular subject for the syllabus prescribed in the regulations ; but that amount of concession to the basic principle is insufficient. It does not go far enough to permit a radical change in the atmosphere of the curriculum, and above all it does not in practice secure to schools the freedom to work out curricula adjusted to the needs of industry and other departments of practical life. The examination system has now acquired such a masterful position in our educational world that what it does not encourage it tends in effect to frustrate. In place, then, of a system which is, in essence, external, though it admits the internal element here and there, we must hope to see installed a system based upon the principle that examinations are to be adapted to teaching, yet designed in such a way as to include the guarantees which the external system offers to parents, employers and the administrative authorities.

For the purposes of the award of National Certificates such a system of examination has already been for some years in operation in the case of technical schools. For example, a National Certificate is awarded under the joint supervision of the Board of Education and the Institution of Mechanical Engineers. The regulations (issued as 'Rules 106' of the Board) provide that courses of instruction shall be submitted by the schools for approval, that the equipment and staff shall also be accepted as satisfactory, and that, when these conditions are complied with, the students of the schools shall be examined by their own teachers in association with assessors appointed by the Institution. The assessors form a Board which has the duty not of imposing uniformity upon the several examinations but of maintaining a common standard which would justify the award of a National Certificate to a candidate successful in any one of them. For this purpose it has the right to substitute a certain proportion of questions for those proposed by the teachers in a school, and of making certain questions compulsory. A similar scheme has been adopted by the University of London for the examination of the twenty-two training colleges allocated to it, the aim being, in this case also, to allow the maximum amount of liberty in teaching while preserving a guarantee of standard.

The methods initiated in these cases would seem capable of being adapted

to the examination of pupils in secondary schools. Questions concerning jurisdiction and the appointment of the Boards of Assessors would present obvious difficulties which it would be premature to discuss here. It need only be pointed out that while the examinations might be, as in the case of the scheme for technical schools, examinations for a National Certificate, there might, on the other hand, be a variety of certificates issued as at present upon the authority of the several universities or of joint boards upon which the universities might be represented together with other authorities. The only other matter that need be referred to is the problem of the school which does not desire or is not competent to examine its own pupils either in the curriculum as a whole or in a particular subject. The solution would appear to be that such a school should be permitted to take the examination of another school chosen for that purpose by itself. Not the least of the advantages of a scheme including this element would, in fact, be that it would give means by which the influence of teachers of outstanding ability or originality might be brought to bear upon their less-accomplished colleagues.

Under certain conditions the universities accept the First School Certificate Examination as qualifying for entry to the university. A certificate with 'Matriculation Exemption' is accepted as qualifying for several professional purposes. Some professional bodies accept the School Certificate without special conditions. The endeavour should be made to secure similar acceptance for the certificate awarded on the internal examination under the proposed scheme.

As regards the universities, it seems reasonable that they should accept the School Certificate as evidence of general education, but might require a special test for admission to a chosen Faculty, unless the Higher Certificate has been obtained.

Second School Examination.

The position as regards the Higher Certificate differs essentially from that of the School Certificate.

In the year 1927, the number of successful candidates for the First School Examination in England and Wales was 35,707 ; the number for the Second Examination was 5,441. The number of candidates from any particular school is small. The standard of the work for this Certificate corresponds to the normal work of the university rather than to the normal work of a secondary school.

The standardisation of this examination for the award of State Scholarships has become very important and it appears better that universities or groups of universities should be the examining bodies for such a purpose. We are of the opinion, therefore, that the Second Approved Examination should remain an external examination so far as the schools are concerned, and are of opinion that no fundamental change is needed in the system with one exception.

The weak side of the present examination appears to be its lack of correlation with higher education in technology, agriculture, commerce, art and music. It is hoped that the Committee on the Relation of Education to Industry (Emmott Committee) may be able to give advice which will help to bring about the desired broadening of the examination

and the correlation of the training preliminary thereto and to specialised study in the various professional groups. Attention should be drawn to the absence of any representation of industry, commerce, art or music on the Secondary School Examinations Council, which is charged with the duty of equating the standards of the various examinations. This Council, however, does not appear to have the duty or the power to consider the broader questions of the influence of the examinations on the schools or the after-careers of the students. A broadening of the functions of the Council and also of its constitution appears to be desirable.

2. Training of Science Teachers.

The following brief statement of the facilities for the training of science teachers is based on inquiries made by the committee at universities, at university college training departments, and at other training colleges offering post-graduate courses in England—twenty-five institutions in all.

Many training colleges do not now distinguish very clearly between training for elementary school teaching, and that for secondary school teaching. Indeed, the Board of Education Regulations for the Training of Teachers now make no distinction between training for primary and for secondary school work. But it is substantially correct to say that the course offered by the various training colleges to men and women who wish to become science teachers in secondary schools is a one-year course of professional training open only to those who have already completed a university science degree course. These post-graduate courses are provided in all the training departments to which inquiries were addressed. The qualifications, therefore, of the teachers trained in the great majority of training colleges where the post-graduate course is not provided do not affect the position of science in schools concerned with the First School Certificate Examination—except indirectly through the elementary education of the boys and girls who pass on from the elementary school to the secondary.

I. The One-Year Post-Graduate Professional Course.

Men and women who intend to teach science in secondary schools usually take a science degree course (extending over three or four years) in a university. The Board of Education's Report of 1925 on the conditions affecting the teaching of science in secondary schools for boys in England contains (page 7) a criticism of the character of the university degree courses considered with reference to their influence on the qualifications of teachers of science in schools and to the need emphasised by the Prime Minister's Committee for science teachers 'with a wider outlook.' The report of 1925 partly attributes to the specialised character of the degree courses the fact that very little has been done to give effect in the schools to the recommendations of the Prime Minister's Committee (1916–1918) that elementary teaching of biology should be a part of the normal curriculum in boys' schools and that courses on scientific subjects or aspects of science other than those dealt with in the normal course

up to the age of sixteen should be instituted for the sixteen-eighteen stage. The report also suggests that courses in laboratory management might usefully be provided as part of the training given in university training departments.

The training usually given in these post-graduate courses includes school practice and observation lessons, formal lectures, discussion lessons, and special courses of subsidiary subjects—such as voice production, black-board drawing, and physical education.

School Practice.

The arrangements for school practice differ somewhat in the various institutions :—

Oxford and Cambridge University training departments send each science student for the whole of one term out of the three to some secondary school for continuous practice under the supervision of an approved science master.

London University departments at the London Day Training College and at King's College send their students for two days a week throughout the year to selected secondary schools under supervision to observe and to teach the particular subject or subjects for which they are qualified. The students are visited at their school practice periodically each term by their tutors and other expert supervisors—practical questions arising out of this teaching being dealt with at a weekly discussion class or seminar. There is also a series of discussion and demonstration lessons in science given weekly in the London Day Training College Demonstration Schools.

At Birmingham (Women's Division) the student takes a self-contained practice teaching course in a secondary school in her principal subject and another such course in her subsidiary subject in a science centre or elementary school.

At Bristol teaching practice is provided in three periods, each of four weeks, the first being in an elementary school immediately after the final degree examination, the second in the middle of the first term of training and the third at the end of the second term, one or (in the case of an honours graduate) both of the second and third periods being in a secondary school.

At Liverpool students intending to teach science in secondary schools have thirteen weeks teaching practice in secondary schools in the neighbourhood.

At Newcastle the student attends one day a week as an observer in his first term at the secondary school in which he is to teach continuously in his second term.

In Manchester half the student's time is spent in school practice under supervision by a tutor with science qualifications.

At Sheffield the student has two continuous periods of school practice in science teaching—one at the beginning of the second term and, in addition, one day and a half each week during the rest of the year he also attends a weekly demonstration lesson followed by discussion.

Of training colleges other than the university training departments, the Cambridge Training College for Women requires students to give two or three courses of lessons each term and to be responsible for the science work in a class for one term in a central, upper elementary, or preparatory school; Maria Grey (London) students teach one or two science subjects in secondary schools during at least four, usually more, periods. The teaching practice of the Clapham High School Training College is carried on both in this school and in other schools and is discussed with the senior subject mistress in the Clapham High School.

While most of the teaching practice is in the special subject which the student intends to teach, most of the lectures attended are common to all students whether science specialists or not, viz., those in the theory and history of education, in psychology, in school organisation, &c. In addition the following specialist lectures are given :—

Special Lectures.

At *Oxford* a short course of lectures is given by the head of a school science department on science teaching, other courses dealing with various branches of science by university lecturers—usually ex-schoolmasters.

At *Cambridge* courses of lectures are given on the teaching of chemistry, physics, and biology.

The *London Day Training College* provides courses of lectures for specialists on methods of teaching (*a*) the physical sciences, (*b*) biological science, not only for its own students, but also for students of other colleges, including King's College. Seminars are held weekly to discuss teaching difficulties and special methods.

Bristol has methodology classes in nature study, botany, and 'science' (with special reference to physics and chemistry). The 'science' class has four preliminary lectures and then breaks up into small discussion groups.

Liverpool arranges for special lectures on the teaching of chemistry, physics, and biology; also tutorial classes for those specially concerned.

Leeds provides a course in scientific method which is usually given by a member of the Department of Philosophy.

Sheffield has a weekly tutorial class in methods and a demonstration lesson followed by discussion in various branches of science.

The Cambridge Training College for Women has a course of ten lectures on science teaching in the Lent Term, and a course of hygiene in the previous term.

Laboratory Management.

Laboratory Management appears to be taught in nearly all the training institutions, but only one of them, Cambridge University training department, mentions a course of lectures (by a local science master) in this subject, including details of the structure of apparatus, the making-up of solutions, and the treatment of accidents in the laboratory. Unlike the two-year training colleges, referred to later, the university training departments are not equipped with laboratories of their own, except the London Day Training College, which has two, one for Physical Science, and one for Biology. The director of the Oxford training department observes it is difficult to get laboratory practice except in the practice school. The Cambridge Training College for Women has one and provides definite instructions and practice in laboratory management and also in *making simple apparatus.*

In most training colleges students usually take methodology courses in one or two subjects outside their own special field. The Cambridge Training College for Women makes teaching practice in general experimental science in the middle school practically compulsory. Manchester has an optional but well-attended course of lectures on the principles of science. In several of the colleges the history, principles and methods of science are, it is said, dealt with in the methodology classes.

The number of students preparing for teaching science in secondary schools ranges in the different colleges from which information has been

received from 7 to 50 per cent. of the total number of graduates in training for teaching. Taking the aggregate of the figures received the percentage is 27.

Neither in the Board of Education's Report of 1925 nor in communications received from training colleges is there any mention of the desirability of disassociating, in the interests of the teaching of science in schools, the ideas of academic honours and specialisation in studies. In the University of London—and the majority of graduates in training for teaching science are London graduates—honours are awarded on the B.Sc. (general) examination under the same conditions as for the B.Sc. (special) examination, that is to say, a student can obtain honours on a three-subjects course instead of on a principal and subsidiary subjects course. It would seem that heads of training departments and heads of university science departments might be got to agree on a policy of recommending students who intend to teach science in schools to take the B.Sc. (general) in preference to the B.Sc. (special) course. Many of the students are probably deterred from doing so by the prestige that specialised courses have acquired through association with honours.

At universities where a diploma in education is conferred, the post-graduate course for intending teachers naturally conforms to the syllabus for the diploma. The main features of a diploma syllabus include :—

1. Theory, principles, and aim of Education.
2. History of Education.
3. Methods of teaching special subjects or groups of subjects.
4. Psychology.
5. School Practice.
6. Essays.

A slightly different emphasis is placed upon these subjects by different universities; in some the history of education is divided into a compulsory section—mainly dealing with the educational system of England and its recent history—and an optional section of a more specialised character, alternative to an advanced course on educational psychology, including practical psychology. Some universities also include hygiene in their syllabus, and some colleges offer courses in voice production, music, drawing, handcraft, and physical training.

II. The Two-Year Training Courses.

These courses are not usually taken by men and women who intend to teach in secondary schools, but by those who normally proceed to primary schools. In the two-year course science subjects are now optional. The table on page 532 shows the extent to which they were offered at the Teachers' Certificate Examination in 1915 and 1927.

In some two-year colleges a much larger proportion of the students include science in their course than is indicated by the figures, since many students taking other principal subjects do include science as a subsidiary. At the Goldsmiths' College, London, about half the men students following the ordinary two-year course, include elementary science (chemistry, physics, and nature study) in their first year's academic course, taking lectures and practical demonstration work in the laboratory. The

laboratory work includes construction and manipulation of apparatus for the type of work suitable for elementary schools. A much smaller number spend about a quarter of their time in their second year in doing more advanced science of various kinds, chiefly chemistry. Goldsmiths' College also offers facilities for a third year course in selected subjects, science being one of them. In accordance with one of the suggestions of the Hadow Report (para. 127), the college is offering facilities to a number of men students to specialise in the group of subjects—science, mathematics, and handwork—the two former being dealt with both in the laboratory and in the workshop and very largely from the teaching rather than the academic point of view. The majority of women students take a first year course in nature study and biology. The figures in the table do seem to show, however, that general effect has not yet been given to the recommendation of the Prime Minister's Committee (1916–1918), viz., that a large number of students in training colleges should be encouraged to take advanced courses in science (para. 88). There has, in fact, been a decrease (from 13·7 to 11·7) in the proportion of students taking those courses, a number even then considered by the Committee as extremely small. 'It is extremely desirable,' said the Committee, 'that there should be a much larger number of teachers in elementary schools qualified to give instruction in science, and that all possible steps should be taken to increase the supply.' One reason for this unpopularity of advanced courses in science may be the circumstance, to which Mr. Lance Jones directs attention (p. 382 of his book on the training of teachers), that although students in the training college are now permitted to specialise in one or more subjects, little use is made of their special qualifications in the elementary schools, a lack of co-ordination which renders much of their preparation of little avail.

Science teaching in primary schools is apt to suffer because of the inadequate provision for practical work and demonstration. Science lessons to be effective need much preparation of material, &c. No allowance is usually made for this in the time-table of the science specialist in the elementary school and the alternatives left to him are either to steal time from an earlier lesson or to do away with the demonstration. The result is that the lessons suffer and the pupil's interest in science is not aroused. Apathy and even antipathy continue through the secondary school and the training college, which sends out teachers with little or no interest in the teaching of science.

When, as does happen, interest is aroused for the first time at the training college, the time available is too short to ensure a reasonable standard of attainment, and—even more important—the student cannot get sufficient practice to enable him to feel confidence in himself as a manipulator of apparatus.

The change-over among women students from botany to biology and the disappearance of 'rural science' are conspicuous, as is the decrease from 51 to 38 in the percentage of students offering elementary science. The Prime Minister's Committee was so impressed by the importance of some scientific knowledge for all teachers that it considered a certain standard of attainment in this field should be required of every entrant to a training college.

Science in Vacation Courses for Teachers.

No account of the training of teachers would be complete which omitted reference to the valuable vacation courses arranged by the Board of Education, local authorities, university bodies and various associations and institutions.

The help given in the refresher courses of the Board of Education is greatly appreciated. The arrangements for 1928 include a course in rural science at Cambridge specially for teachers in elementary schools. The Board has also arranged courses for teachers in secondary schools in physical chemistry at Oxford, in biology and botany at Cambridge and in physics at Harrow. There is also a course for teachers of domestic subjects in dietetics to be held in London.

Of the local education authorities, Cheshire provides courses in chemistry and biology, Glamorganshire in general rural science, Hertfordshire in horticulture, Kent in handicraft in relation to science and nature study, and the study of plant life, and Yorkshire, West Riding, in nature study. The Oxford University Training Department includes natural science among the subjects in their course on education which, under certain conditions, admits to the examination for the university diploma in education. The Educational Handwork Association provides courses in science handicraft, nature study and rural science.

The value of such courses as the above, when they include a considerable amount of practical work and discussion, can hardly be overrated. They give opportunities to teachers in elementary schools to be brought into touch with the university lecturer who is able to put the rudiments of the subject as viewed in the light of the latest research. The secondary school teacher has opportunities of developing special craft skill or of hearing recent developments in his own particular subjects. The courses, moreover, offer an opportunity, not so widely used as it might be, of broadening the scientific interests of those science masters who have been somewhat exclusively trained in the direction of physics and chemistry. The intensive biological course under summer school conditions has proved of very great value to those whose business it is to face the problem of science teaching on broad lines.

A new syllabus for rural science has been drawn up by the Departmental Committee on Rural Education so that entrants to a training college who qualify by means of this new alternative examination must have reached a definite standard of attainment in science and in the mathematics thereof. The syllabus is issued by the Board of Education and by the Oxford and Cambridge School Certificate Authorities. The Departmental Committee is hopeful that the lead it has given in this way will make itself felt in the training colleges.

In this connection reference may be made to the Committee's recommendation that the elements of natural science should be a compulsory subject in the Public Schools Entrance Examinations—although this is not relevant to the questions of the training for teaching in secondary schools except in so far as concerns the importance of the first steps in the study of science. On this point the Secretary to the Common Entrance Board observes that at one time a ' nature study ' paper used to be set

at the common entrance examination, but this was dropped some years ago, and now there is no direct paper in science and only a scientific tendency in some of the mathematical questions, the geography paper and, sometimes, an essay. That science does not at present take a very formal place in preparatory schools is not, he says, due to lack of will on the part of the headmasters, but really to a lack of time and suitable teachers. He has reason to think that an increasing number are interested in the matter and are introducing perhaps informal lessons into their schools.

3. The Relation between the Supply of Teachers of Science and the Science Subjects Taught in the Schools.

It is obvious that the science subjects taught in the schools give a bias to the intending teacher and that the course taken by a student at the university tends to decide the nature of the science teaching in the school to which he or she goes as a teacher. In this connection the size of the schools is worth consideration. It seems safe to say that where a school contains 150 pupils or under the teaching of science will be in the hands of one teacher, and that where that teacher is a one-subject specialist the teaching will tend to be limited, particularly in the upper parts of the school, to the subject in which specialisation has taken place. The Statistics of Public Education show that of the 1,301 secondary schools on the grant list in 1925–26, 629 contained 250 or under pupils, 445 contained under 200. In 1926 it was found as a result of an exhaustive enquiry into the supply of teachers made by the Joint Committee of the four Secondary Associations that of 100 teachers offering science subjects, 38 offered chemistry, 23 physics, 12 botany, 15 science (kind not specified), 12 natural science. The relation of the demand for science teachers to the general demand is shown by the fact that of 100 vacant posts in the same year, 1926, 12·2 were for physics and chemistry, 11 for mathematics, 1·9 for botany, 0·9 for biology. While the teacher of biology is generally competent to teach introductory physics and chemistry, the teachers of these subjects are not as a rule either willing or competent to undertake the teaching of biological science. In the course of the above-mentioned enquiry returns were received from schools and the following table shows the distribution of the study of science subjects among the pupils in post-matriculation forms in 232 schools :—

	Maths.	Science[1]	Chemistry	Physics	Biology	Botany
1st year .	90	74	47	29	9	4
2nd year .	102	62	39	51	15	4

No figures are available at present in regard to the number of entrance scholarships available at universities and the proportion of these allotted to the different science subjects, but the following information relating to State scholarships shows the same concentration on physics and chemistry.

[1] Some schools gave the number of pupils studying science without indicating the nature of the science in question.

STATE SCHOLARSHIPS IN SCIENCE.

	1923–1924		1924–1925	
	Boys	Girls	Boys	Girls
Science, Physics	12	1	10	2
,, Chemistry	27	1	26	2
,, Combined Physics and Chemistry	4	1	5	1
,, Biological Group	5	3	6	4
,, Geological Group	1	1	1	0

The information available for 1926 and 1927 does not give the distribution to boys and girls, but the total awards in the science subjects are shown below.

NUMBER OF STATE SCHOLARSHIPS AWARDED IN SCIENCE SUBJECTS AND THE DISTRIBUTION AMONG THE VARIOUS SCIENCE SUBJECTS.

	1926	1927
Physics	11	7
Chemistry	19	9
Biology	5	7
Engineering	4	3
Other Science	8	8
Total Science	47	34
Total Scholarships taken up	225	172

It is not surprising to note that the students of science in training departments of universities also show the same preoccupation with physics and chemistry as indicated in the following statistics for 1926 :—

	Maths.	Chemistry	Physics	General Science	Botany
Bristol	3	4	2	—	—
Manchester	5	13	8	3	1
London Day T.C.	10	12	8	—	8
Sheffield	2	5	3	—	—
Cardiff	—	4	3	—	2
North Wales	3	7	4	—	—
Swansea	—	—	—	—	2
Reading	1	2	1	—	3
Cambridge (women)	5	—	—	5	—

Students who have been trained will have had their attention directed to the desirability of breadth of curriculum and it is to be regretted that a large number of intending science teachers do not take any training course.

There was, and is still to some extent, a tendency to require that teachers shall hold honours degrees in their subjects. Of fourteen mathematics posts advertised in the *Times Educational Supplement*, from October 22 to November 12, seven called for honours degrees in the applicants. During the same period it was stated in eight out of sixteen advertisements for teachers of specified science subjects that honours or high honours were necessary. Of six vacancies for general science, one asked for an honours graduate.

4. Reform in the Teaching of Science.

The Basis of Science Work in Schools.

A reform in the methods of teaching science in schools is long overdue, and the need for a strong lead in the matter is evident. There is widespread dissatisfaction with the present position—a dissatisfaction as much amongst teachers as amongst leaders of educational thought.

Since school life extends over a long period of years with well-marked divisions representing big differences in the needs, outlook, and ability of the pupils, it will be useful to define these periods in order to avoid any possible misunderstandings of the object and applications of any recommendations the Committee may make.

School life from the point of view of mental development may be considered to consist of three fairly distinct periods :—

1. The primary school period—for children from the age of 7 to 11.
2. The first stage of the secondary school period from 11 to 16 years, including the adolescent period.
3. The second stage of the secondary school period—the intermediate university stage from 16 to 19 years.

From the point of view of science teaching, the first stage of the secondary school period is the most important one, and it is with conditions during this period the Committee is mainly concerned. Under the age of 11 formal science instruction is, by general consent, out of place, although a carefully arranged scheme of nature study is applicable, and a valuable preparation for the work that follows later. The majority of boys terminate their school life at not later than $16\frac{1}{2}$ years of age ; at present most of those who stay on at school beyond that age may be regarded as preparing for continued education at a university, or for some one of the many professional courses of university standard. These are the specialists, and need very different treatment from those of the middle period. Their success and progress will largely depend upon the soundness of the work done in the earlier stages. Apart from this general link the specialist group can take care of itself, for the character and content of their syllabus will be determined mainly by university requirements. It is, therefore, to be understood that the following suggestions and recommendations apply only to that big middle group of boys or girls who for the most part leave school before they are about $16\frac{1}{2}$ years old.

The content of the science course for this group should be broad rather than deep, and should include those subjects that will enable the pupil to enter into a real understanding of his, or her, physical environment.

School science may be said to be concerned mainly with the simpler aspects of the changes in matter accompanying transformations of energy, whether in the living or non-living forms.

The difficulty confronting the Committee lies, not so much with the selection of suitable material for school work which a youth of 16 or 17 might reasonably be expected to know, but with the far greater problem of explaining how this mass of stored-up knowledge should be dealt with by the teacher in order that it may become part of the boy's own experience, and usable in his everyday contact with the world. In other words, it is the method of teaching science that needs to be outlined and broadcast as well as a syllabus of the various sections of knowledge recommended. Account would have to be taken of the suitability of the syllabus for the age of the pupil, the time allotted to the subject on the school time-table, the correlation of effort in various directions to link up the subject with the teaching of English, mathematics, and geography, and further the conditions under which those methods can be applied, and which are inseparably connected with methods of teaching science. Any pronouncement, therefore, to be of value would have to indicate at the same time the necessary arrangements and equipment of the workroom, the nature of, and the supply of, apparatus and material required.

A brief statement of the basic principles of education by way of introduction to the course advocated seems to be called for in order to justify the claims advanced that a study of science is an essential part of a general education.

Science can only satisfy these claims if the methods employed are based on principles fundamental to all educative processes.

Education is the outcome of experience, and of experience only. School is a place in which a special environment is arranged to afford experience partially or wholly unattainable in ordinary everyday life outside, but organised and regulated for speeding up the process of education in such a way as to render a boy fit to take his place in society on reaching manhood's estate. The process of mind-development in school is in no wise different in its physical and psychological form from that in any other environment. If, therefore, it is recognised that all subjects of a school curriculum must conform to this principle, it follows that the first and predominating feature of science work in schools, for the period stated, must be its practical basis—that is, contact with life at every stage.

Knowledge is gained only as a result of experience, although it may be amplified and deepened by information communicated through speech and book. The use of knowledge is its aid to thought, and only in that sense and for that purpose is knowledge of value. Knowledge is incidental to the process of undergoing experiences—so that it is experiences and not knowledge that should be the basis of a science course.

A science syllabus, to be of any value, should indicate the track or method by which it is possible to promote these experiences. It must indicate how the teacher can lead the pupil through experiences that are

fruitful, purposeful, and of permanent value; how he can utilise the interests and aspirations of the pupil to make those experiences real and a part of his everyday existence. In this connection the Committee desires to emphasise the prime necessity of broadening the basis of science instruction in schools, and to urge the inclusion in the school curriculum of only such parts of any particular branch of science that are considered fundamental from an educational point of view, and considered necessary for a clear understanding of those natural phenomena with which a well-educated youth, and not an expert, might reasonably be expected to be familiar. Only to the extent that school science can do this will it fulfil its purpose in contributing to the development of capacity for self-education when the controlling influences of school days are over. It is experience that matters; the mere acquisition of facts is relatively valueless. The growth of power to deal rationally with any subsequent situation that may confront the individual is of far greater importance.

Drawn up on these principles the science syllabus would start with the boy or girl as the basis of consideration rather than with an examination to be passed at the end of four or five years. It would take into account the pupils' ability, their intellectual limitations, their interests and needs at different ages. It would also include within its range contacts with the literary side of the school curriculum in order to identify its cultural possibilities with the highest the school can give.

Given the necessary freedom the study and training in science associated with literary work should lead the growing boy, or girl, to a fuller appreciation of the verities of life, to something larger, loftier in their outlook than anything that could be offered by a literary training alone.

The Committee feels that the majority of syllabuses prescribed at the present time for this particular part of school life are too rigid, too much influenced by college requirements, or by the standard demanded for university scholarships. It therefore advocates a complete breakaway from the present course, which has little to recommend it except the ease with which it can be brought within an examination system.

Most examination syllabuses ignore the great difference in the mental powers of the pupils between the ages of 11 and 14 as compared with those between the ages of 14 and 16. The ordinary four- or five-year course apparently provides work to be done at the rate and standard at which a pupil of 16 would work. It ignores the fact that, for the first two years, the work must be simpler and of a different type from that of the last two years, and must proceed at a slower pace. The difference is not one merely of range and depth of knowledge—the reasoning powers have to be developed, good habits of judging and reflecting engendered. It is growth that has to be encouraged; the acquirement of information is only incidental.

Examinations may be necessary at the end of the school course, but their influence during the earlier years of a secondary school course should be directive rather than controlling. They offer wrong values to the pupils because they, the examinations, and not the subject, are made the objectives of the work done. Teachers need freedom to educate, and freedom to work without being compelled to cram for examinations.

5. Training in Scientific Method through the Study of Biology.

The claims of biology to a place in the curriculum of schools—its value in studying living things, its bearing on human life, its enquiry into the wide questions of heredity and evolution—have been acknowledged in many quarters, but it is not often urged that through the study of biology a training in scientific method can be given.

Prof. Bateson, in the Huxley Centenary Number of *Nature*, said of that great biologist, ' No one better than Huxley knew that some day the problems of life must be investigated by the methods of physical science, if biological speculation is not to degenerate into a barren debate.' It will be of interest to quote what Huxley himself said in his lecture ' On the Educational Value of the Natural History Sciences,' though we think he would not now describe experiment as ' artificial observation.'

He said ' The subject matter of biological science is different from that of other sciences, but the methods of all are identical; and these methods are :—

1. *Observation* of facts—including under this head that *artificial observation* which is called experiment.

2. That process of tying up similar facts into bundles, ticketed and ready for use, which is called *Comparison* and *Classification*—the results of the process, the ticketed bundle, being named *General Propositions*.

3. *Deduction*, which takes us from the general proposition to facts again—teaches us, if I may so say, to anticipate from the ticket what is inside the bundle. And finally—

4. *Verification*, which is the process of ascertaining whether, in point of fact, our anticipation is a correct one.

Such are the methods of all science whatsoever.'

This scientific method of studying biology presents many difficulties in schools, and involves much more thought and time on the part of the teacher than teaching by imparting information, but it can be done and is of much greater value.

With regard to the observation of facts it is unsatisfactory for the teacher to show the class one or two experiments, or even for the pupils themselves to make one or two experiments, and then proceed to general propositions. In biology generalisations should not be made on insufficient data any more than in other science. As many experiments should be made as possible in the lesson, and records can be kept each year of the results.

If this is done the pupils, after they have made their own experiments, can have before them the results of hundreds of similar experiments in addition to their own, before they generalise, and yet not spend a great amount of time in any one year.

Take, for example, the green plant, ' the main link between the inorganic and the organic ' as it has been called, and its work in photosynthesis, the work on which the life of the world depends. It is possible, for some successive years at all events, to arrange that each year each pupil investigating the formation of sugar and starch by green leaves in the presence of light and carbon dioxide, shall take leaves other than

those taken before. After each pupil has obtained the results of her own experiments the results obtained by all the members of the class can be compiled, and *then* compared with the results of experiments in former years. In this way reference has been made by girls at James Allen's School, Dulwich, to hundreds of experiments on the formation of starch by green leaves before any generalisation has been made in the matter. Pupils of post-matriculation stage can verify the results obtained by treating the whole leaf with iodine by treating sections of leaves.

Other experiments which afford training in scientific method are those of pollination. The function of pollen need not be told. It is quite simple for pupils to make their own experiments, to ascertain a number of facts for themselves, to compare results and to draw their own conclusions. But, in these experiments, as in others, care must be taken to have control experiments. In the James Allen's Girls' School, Dulwich, where less than one hour a week for one class only in the summer term of each year was allotted to experiments in pollination, successive classes recorded their results, and more than two thousand results showing the function of pollen are available for reference. Also the results of more than five thousand experiments, showing in which flowers self-pollination can take place, have been put on record, in some cases the information not being available in any book.

Numbers of experiments can also be made on the influence of gravity and the influence of light on the direction of growth of roots and stems.

Classification of plants may be taken in a scientific way. If carefully selected plants are taken in the early stages of plant study, pupils later on may be able to compare the leaves and the structure of the flowers of many plants, group together those plants possessing the same characteristics, and arrive at a system of classification from the previous observation of facts.

For pupils of *post*-matriculation stage experiments to investigate Mendel's Laws of Heredity—laws which were first discovered by Mendel's work on *plants* in an ordinary garden—can be of great value and of absorbing interest. Elder pupils may make experiments such as crossing pea plants having yellow cotyledons with those having green cotyledons, and other simple experiments.

In making the experiments quoted above, and in many others, pupils studying biology can be trained in observing facts, in comparing the results of their own observations with those obtained by others, in drawing conclusions from a great number of facts and in verifying those conclusions. By means of experiments they can make discoveries for themselves, a source of pleasure to many, though all cannot say with Boyle ' In my laboratory I find that water of Lethe which causes that I forget everything but the joy of making experiment.'

But it is well to emphasise the necessity of rigorous examination of the conditions of the experiment and the value of control experiments, and in all cases it is essential that any results, not in agreement with the greater number, should not be slurred over, but carefully considered, suggested explanations of the discrepancies being obtained from members of the class and discussed.

6. ON BIOLOGICAL TEACHING IN SCHOOLS.

[Extracted, by permission, from the Report of the Committee[1] of the Meeting of British Zoologists, appointed January 1927, 'To consider the position of Animal Biology in the School Curriculum and matters relating thereto.']

It is scarcely necessary at this time to labour the point that biological teaching should have *some* place in the education of our children; the principle is now very generally admitted, even though there remain a number of schools in which such teaching is limited to a little desultory 'nature-study' in the lower forms. The question of the amount and scope of biological study to be recommended, however, requires careful attention and involves some serious consideration of the already much-worn topic of the aims and limits of school education. It would be tedious to repeat even a few of the many definitions in vogue—suffice it to remark that human education may be considered under two aspects, the vocational and the cultural, and that of these we hold that the latter is by far the most important in our schools, since (in training pupils of under sixteen years of age at least) the aim should be, first and foremost, to ensure even and healthy development of the pupil's powers, and second, to lay the foundation of a wide range of intellectual interests which may 'increase the capacity for imaginative experience.' But this should not be taken to exclude a 'realistic' or 'pre-vocational' element, which may be introduced with great advantage to the cultural aspect of the work, stimulating interest by linking the school life to life in the larger world for which it is a preparation.

The growing plant or animal in favourable natural surroundings is 'educated' to even and healthy development by the stimulating action of the various factors in its environment; it is one of the great difficulties in human education to select from the overwhelming complexities of the social and physical environment of civilised man such factors as may best afford a balanced stimulation. The guiding principle in selection should be the appeal to nature; the main endeavour, to encourage the development of the natural interests of the pupil in the order in which they naturally show themselves.

From first to last the growing child is fundamentally interested in the natural world of living creatures about him and in his own physical relations to the general life—a second interest, a concern for his own relation to the social scheme of human life in particular, grows steadily in force especially throughout the period of adolescence. Each of these two interests can best be served and utilised by the inclusion of biological studies in the scheme of education—the second interest no less than the first, since the social and economic development of the human community is conditioned ultimately by biological laws, as an unbiassed consideration of any given political or economic problem will show.

To ensure some degree of appreciation of the inter-relationships of all living things and of their ultimate dependence upon physiological and physico-chemical factors is the surest way to extend the consciousness of the pupil beyond the narrow sphere of individual entity, and to lay the foundations of a genuine and enlightened philosophy of life—'to see life steadily and see it whole'; education in its cultural aspect can have no higher aim.

But if its aim be such, biological education must be 'biological' in the fullest sense—must take as field the whole range of life, plant and animal kingdom alike[2] and man in his own place—but must not, however elementary the instruction, ever sacrifice its breadth of view. A casual lesson-series now on the butterfly, now on the buttercup, now on the kangaroo, now on the much-martyred bean-seed, dealing in no sort of sequence with such topics as the names of the parts of a flower and the number of toes on pussy's foot, will serve no purpose in the general scheme, and scarcely more

[1] Members of Committee:—Prof. R. Douglas Laurie, Department of Zoology, University College of Wales, Aberystwyth (Chairman and Secretary); Howard W. Ballance, Biology Master, King Edward's School, Birmingham; Kathleen E. Carpenter, Department of Zoology, University College of Wales, Aberystwyth; William J. Dakin, Department of Zoology, University of Liverpool; Oswald H. Latter, Senior Science Master, Charterhouse; Prof. E. W. MacBride, Imperial College of Science and Technology, London; Mary McNicol, Biology Mistress, Manchester High School for Girls; Alice J. Prothero, Biology Mistress, Aberdare Girls' County School.

[2] This has been recognised in other countries more than here.

will be gained even by a well-planned course in botany alone throughout a number of years in school life ; we may go farther and suggest that even parallel courses in botany and zoology, run on separate lines, do not constitute truly ' biological study ' and will not, unless unified by the philosophic approach, contribute greatly to the end in view, if that end be cultural, as defined.

From the standpoint of intellectual training in the schools, biology has been the subject of a great deal of criticism ; its methods have been stigmatised as somewhat vague and, while inculcating at best a habit of close observation, as unlikely to afford a training in accuracy of method and inductive argument equal in value to that given by the physico-chemical sciences. The answer to such a charge is best supplied by a reference to the altered trend of modern biological science which, so far from concentrating on the morphological details which once obscured its horizon, is now in large measure concerned with physiological, ecological and economic topics. The extension of our knowledge of the principles of these latter relationships has made it possible to apply them to the conduct of even quite elementary biological work, and a course arranged in such a way cannot fail to give strict training in accuracy of method as well as observation, in inductive as well as deductive reasoning.

The vocational aspect of school education is matter for serious debate ; the general vocation of all pupils is citizenship, and the importance of biological studies for this end has already been urged. In the higher tops of the elementary school, in the central school and in the middle forms of the present secondary schools, say from the age of twelve to sixteen, the occupations followed in the locality may with great advantage be drawn upon whenever appropriate, as for example in agricultural districts, without rendering the training ' vocational ' in the proper sense of the word.[3] With regard to special vocational studies, we think that such should not be undertaken by pupils under the age of fifteen or sixteen.

To summarise, some general guiding principles may be set forward, as follows :—

1. The general aim of school studies in biology should be to inculcate a sound appreciation of the natural laws which govern the lives of human beings no less truly than they do those of other animals and of plants.

2. The basis of the study should be close observation of plants and animals in relation to their natural environment, and not as self-contained entities.

3. Morphological study should be undertaken less for its own sake than for that of its fundamental importance in the study of organic function.

The actual building of a detailed scheme of work to range throughout the school in accordance with those principles requires a great deal of close discussion. The following general suggestions are made :—

(*a*) The biological work of lower forms should consist mainly of direct observational study of plants and animals on heuristic lines and using living specimens whenever possible ; simple morphological study should be throughout related to physiological and ecological principles, growing plants and living animals (such as pond-animals, earthworms, &c.) should be kept in the classroom and collected and tended by the pupils themselves, and visits to museums, parks and botanical and zoological gardens should be made as frequent as possible.

(*b*) Biological study in the middle school should be correlated with work in elementary physics and chemistry ; a special feature should be made of simple experiments illustrating the fundamental processes of respiration, assimilation, &c., in plants and animals alike, and their essential similarity to the corresponding processes in man should be emphasised. The ease with which a number of physiological principles can be demonstrated on the human subject should be borne in mind. The idea of evolution should be implicit, and some indication given of the interrelations of biology and social science. At this stage human occupations, particularly those followed in the locality, should be drawn upon as providing mental stimulus.

(*c*) For pupils above the age of sixteen, more detailed morphological study of animals and plants should be undertaken, but the greatest importance should be attached throughout to the elucidation of the functioning of organs, and of the organism as a whole, to ecological and bionomical relationships, and to the part played by the individual and its race in the general economy of life. The interest of animals and plants as factors in human culture and civilisation should be indicated and the influence

[3] We would take this opportunity of expressing ourselves in sympathy with the general suggestions made in the Report of the Consultative Committee on The Education of the Adolescent. Board of Education. H.M. Stationery Office. 1926.

of man on the distribution of other organisms touched upon. Reference should be made to the fundamental facts of geographical palæontology. Group personal investigation work should be carried out on simple but scientific lines. Some appropriate elementary chemistry should be here included if the pupils have not already the requisite knowledge in this direction for a study of the desirable physiological work. The work at this stage will generally fall within the scope of Higher Certificate courses, and in view of the fact that there is an increasing tendency for the Higher Certificate to become the entrance requirement of the universities it would appear imperative that the universities and the school teachers should consider in co-operation the arrangement of the work in relation to both the school and university standpoints.

With regard to syllabuses, we deprecate uniformity; we would prefer to see different syllabuses elaborated in various localities in accordance with local conditions. We feel that it is fundamental to encourage individuality in teaching; on the other hand, it is desirable that the standard of achievement aimed at should be as far as possible uniform.

OUTLINE PRINCIPLES AND GENERAL SCOPE OF THE SYLLABUS IN BIOLOGY FOR PUPILS OF 11 to 16 YEARS.

The Syllabus should be drawn up in such a way as to avoid the complete separation of plants and animals into two unrelated 'kingdoms' for independent study. It should be arranged with a view to emphasising their fundamental resemblances as well as their differences, since the latter can hardly escape attention, while, unless caution be used, there is some danger that the former may be overlooked.

The study of function should be stressed throughout; morphology should be dealt with in sufficient detail (*a*) to assist in the understanding of function, (*b*) to lay the foundations necessary for a grasp of the idea of evolution.

The study of organic evolution should be implicit in the general arrangement of the syllabus, rather than a matter for separate consideration; a simple account of the struggle for existence should, however, be given.

To ensure the emergence of the idea of evolution it would perhaps be best to arrange the course so as to commence with the simpler forms of life and lead gradually up to man, but for the understanding of the relations between structure and function it is best to commence with higher types—flowering plants, frog and man, and so to proceed from the known to the unknown rather than from the simple to the complex; on balance it seems best to recommend commencing with the higher vertebrates.

Physiological experiments should be introduced not only in regard to plants but also animals; it is a grave mistake to suppose either that animals do not lend themselves to simple experiment as readily as plants or that such experiments must involve suffering.[4] Many simple but useful physiological observations may be made on the human subject direct, for example, counting the pulse and heart-beat, testing the action of saliva on starch, demonstrating the evolution of CO_2 in respiration, the excretory function of the skin, and a variety of observations on the senses.

Consideration should be given throughout to the relation of the organism as a whole to its natural environment and to the inter-relations between all the living creatures which make up a biological community. Reference should be made, wherever possible, to local industries in their relation to the biology of human communities. Biographical notes on a few pioneers such as Darwin and Pasteur may be introduced in illustration of the relation of Biology to human affairs in general.

Practical work should include observations on living organisms in their natural surroundings, experiments on their physiology, and the keeping of aquaria, terraria and a school garden. The use of the microscope[5] should be encouraged, but no great stress laid on the elucidation of minute structure. There should be some dissection of animal specimens sufficient to display the broader anatomical features; whether the dissection should be performed by the pupils themselves or by the teacher in their presence must be largely determined by the time and facilities available.

[4] See W. J. Dakin's 'Elements of General Zoology.' Oxford Univ. Press, 1927.

[5] For work up to School Certificate standard a single microscope at a cost of £3 will go a long way. Such an instrument is supplied by C. Baker, 244 High Holborn, London, W.C. 1. It has a range of magnification of $\times 25$ to $\times 220$, covering ordinary 'low power' work.

Instruction in the physiology of reproduction and sex should be given, but if the syllabus be well planned such instruction will occur naturally in the course of the general work, and not as a matter for special and separate consideration. Teachers are therefore relieved of the invidious task of giving the child sex instruction based upon human physiology, the essential facts being learned in ordinary school work.

7. Scheme of Biological Science in a Secondary School.

By C. von Wyss, F.L.S. (Lecturer in the London Day Training College, University of London).

The following scheme is planned for a four years' course in a secondary school. Biology is intended to be the central science and should, therefore, occupy a minimum of three hours a week. Thus, assuming that five hours are assigned to science, time is allowed for contributory studies in physical science. The course is intended to provide for the pupils' experience and discipline in elementary natural science and to emphasise by means of such experience the main biological discoveries and conceptions.

The general method of procedure is intended to be as varied as possible, but whether the lessons take the form of demonstration by the teacher, investigation and experiment on the part of the pupils, or free discussion in class, the central element of all procedure will be the pupils' practical experience. While it is definitely intended towards the end of the course that the pupils should become acquainted with biological theory, this should be richly illustrated by a body of concrete fact, into the possession of which the pupils have come in the course of their own studies. The complete course will explore the main region of biology, viz.: (i) the drama of life; (ii) the unity of life; (iii) continuity of life; (iv) web of life.

It is taken for granted that the formal work of the laboratory is supplemented by field work and rambles, that gardening is brought into close correlation, wherever opportunity presents itself, that holiday work is encouraged and organised and that a natural history society promotes individual and original investigation.

First Year.

The foundation of biological science is a disinterested love of nature. Children are normally interested in their natural environment and in out-door pursuits and the biology lessons are intended, primarily, to foster and educate this interest and curiosity. Care must be taken to encourage the habit of first-hand observation and independent thinking by providing experience which arrests attention and prompts questions. While fully realising the importance of securing intellectual values, the cultural aspect of the enjoyment of beautiful things and events is definitely recognised.

It is entirely in accord with the conception of an approach to the study of living things, that the work should be seasonal. The studies are thus made more real and vivid, ensuring for the pupils the primary and fundamental nature impressions.

Autumn Term.

1. Study of a few typical flowers, *e.g.* Snapdragon, Nasturtium, Scarlet Runner, Sunflower, with a view to discovering the general plan of a flower, the persistent parts and the formation of fruit.

2. Life-history and habits of such insects as wasps and humble-bees, which are so numerous that they claim attention. The discussion of the ways of these insects will probably lead to observations on ants and a study of their life-history. It is easy at this time to obtain caterpillars of the Cabbage White butterfly, for which the pupils could make simple breeding cases. Experiments could be made on colour adjustment in larvæ and pupæ by keeping them in boxes lined with paper of different colours.

3. Other suitable animal studies, providing opportunity for individual or group work, can be carried out on earwigs, centipedes and millipedes, spiders.

4. Examination of various kinds of bulbs and corms. Critical consideration of various methods of planting bulbs for indoor culture. Planting bulbs for class-room decoration and a possible flower show in spring.

5. Leaf-fall. Making a collection of leaves of different trees, mounting and

naming them. A suitably decorated portfolio for the leaf-collection might be prepared in a craft course.

6. Snails and earthworms. Construction of a wormery.
7. Winter sleep of animals and plants.
8. Christmas tree and other evergreens.

Spring Term.

1. Trees in winter: recognition by (i) branching, (ii) bark, (iii) buds. Examination of buds. Brussels-sprouts and cabbages reveal the general structure of leaf buds on a large scale.

2. Seed-sowing. Study of familiar seeds. Seeds planted for purposes of observation, in lamp-chimneys, gas-jars or test-tubes, lining these with blotting paper, placing the seeds between blotting paper and glass and keeping the apparatus moist. Records of growth. Simple experimental study of the conditions necessary for germination.

3. Winter-residents among the birds. Learning to identify familiar birds. Making observations and records of their habits, call-notes and song. Such bird studies could be continued by individual pupils on the migrants of the locality.

4. (*a*) Awakening pond-life. Frogs and newts. Frog-spawn should be looked for in February and brought into the laboratory for observation and records of development.

(*b*) Awakening life in wood and field: Squirrels, dormice, hedgehogs, wood-mice.

5. Study of spring flowers: Records of growth of bulbs planted in the autumn and a comparative study of their flowers. Other spring flowers, such as violets and primroses.

Summer Term.

1. Plant life. Typical spring and summer flowers; need for classification; natural orders; how to use a 'Flora.' Making a herbarium of wild flowering plants would form suitable summer holiday work.

2. Study of the growth and metamorphosis of tadpoles continued. Visits to the pond lead to the discovery of other curious pond creatures, *e.g.* dragon-fly, caddis, water-beetle, water-boatman, water-spider, stickleback. These should be accurately described and their habits studied and recorded by individual pupils or groups.

3. Construction and maintenance of an aquarium. Water plants.

4. Study of soil. General character of clay, sand, chalk, peat, &c.; character of local soil and sub-soil. Simple experiments to ascertain the proportion of the various constituents of a sample of soil. Water-content. Effect of 'liming' clay soil. Leaf mould and humus: origin and distribution. Why the farmer thinks soil itself 'alive.' Soil bacteria and protozoa needing air, water and food.

SECOND YEAR.

A large and varied number of forms and phases of animal and plant life having been studied in the previous year, the pupils are now able to discuss and appreciate the only factor common to all, viz., 'aliveness.' Investigating this quality certain fundamental attributes are found, all of which are characteristic of animals and plants. These are growth, reproduction, locomotion (rare in plants), nutrition, respiration, excretion and response to stimulus. Contrary to the usual practice in studying biology by examination of the structure of dead and preserved specimens, it is intended in this scheme that the study of the function of the living animals be emphasised. It is, however, recognised that neither function nor habit can be rightly understood without reference to structure.

Although much is to be said in favour of beginning the study of animal and plant biology with the higher and more familiar organisms, the relations between the simplest organisms and the environment are so direct and fundamental, that they are more likely to come within the grasp of young students. The element of surprise and wonder which accompanies the introduction to the study of micro-organisms certainly stimulates interest. The microscope work which it entails is a training in laboratory technique which is in any case sooner or later necessary. In order to reduce the number of pupils, on account of the space, apparatus, specimens and supervision required, the classes are intended to work in parallel divisions, as they would in physical science lessons.

Autumn Term.

1. The study of some typical unicellular organisms, *e.g.* Amœba, Paramœcium, Euglena, Vorticella, Protococcus.

2. The relation of function to structure in multicellular organisms, *e.g.* Hydra, Earthworm, Fucus, Fern. Simple dissections are necessary.

3. The study of a bird's skeleton as a striking example of adaptation of structure to function. A comparison with our own skeleton is profitable.

Spring Term and Summer Term.

1. Experimental study of plant physiology and the general structure of flowering plants: Growth and development of root and shoot, regions of maximum growth. Reactions to gravity, light and water. Respiration. Passage of water through the plant and transpiration. Nutrition: minerals from soil, carbon assimilation and photosynthesis, food stores.

2. Study of the reproduction of flowering plants. Simple experiments in pollination of flowers. Study of highly specialised structures ensuring cross-fertilisation. Significance of cross and self-fertilisation. Parthenogenesis.

3. Formation and structure of typical fruits.

N.B.—As some of the experiments in plant physiology, *e.g.* those on photosynthesis, cannot be carried out with reasonable success in winter or early spring and many flowers can be studied early in spring, the work of the spring and summer terms cannot be kept strictly apart.

THIRD YEAR.

The pupils' studies of animals and plants and of the common factor of their 'aliveness' having reached the problems of reproduction and associated specialisation of structure in plants, the subject of the continuity of life receives attention. It is important that the pupils be shown how to make personal observations in the field which bear on the subject in hand. As a model of method in this procedure they should become acquainted with Gilbert White's Selborne. Their laboratory work also should become amplified and supplemented by wide and generous reading, so that the results of their own experiments and observations may be viewed in proper perspective.

Autumn Term.

1. Result of the summer activity of plants: seed formation. The class should count the number of seeds produced by single plants of many different kinds and estimate the number of young plants produced. Account for the difference in these numbers, finding evidence out-of-door for all explanations provided. Much of this work is done individually or by small groups and the results are contributed to a class-record.

2. Special adaptations in fruits and seeds for successful dispersal.

3. Study of the productivity of some animal types, *e.g.* green-fly (aphis), wasps, spiders. Examine Linnæus' famous statement, 'Tres muscae consumunt cadav r equi, aeque cito ac leo.'

4. Evidences of a struggle for existence and continuance.

5. Contrivances in animals and plants which make for success in the struggle. Special modifications of structure. On this subject the pupils' out-door observations must be supplemented by visits to museums and reading.

6. All the seeds produced by one species of plant are essentially alike, so are all the leaves of any one species of tree. Challenge the class to find two beech leaves or two bean seeds alike in every respect.

7. The class should measure the length of several hundred bean seeds (of one kind) and plot a graph showing the number of seeds for each increase in length of 1 mm. between the minimum and maximum. Similar graphs can be constructed on the weight of these seeds, on the number of prominent veins on each side of several hundred beech leaves. The pupils will not only see that similar individuals vary, but that they vary in a certain way.

8. Discussion of the possible origins or variations.

Spring Term.

1. Asexual reproduction in plants and animals.

2. Revision of the main facts of sexual reproduction studied in the previous year in connection with hydra, worm, frog, &c., and the higher plants.

3. Detailed study of eggs of fowl, water snails, slugs and (later in season) caddis-fly. Main phases of development of embryo.

4. Influence of environment on developing organisms.
   (i) Feeding experiments with tadpoles.
   (ii) Caddis worms and water snails reared in vessels of different capacity.
   (iii) Water-cultures of seedlings and cuttings.

5. Structure of the cell and simple account of nuclear division (mitosis and meiosis).

6. Discussion of the phenomenon of inheritance and the relation of nature and nurture.

Summer Term.

A 'regional study' of a pond (if this is impossible a piece of waste land, a hedge-row, a common may be studied).

A pond being a small and compact entity provides an example of a closely inter-related community of organisms in which their life, behaviour, relation to each other and to their environment can be studied.

This study should include records of the physical conditions of the pond and the preparation of diagrams of transects to show the distribution of plants.

FOURTH YEAR.

The pupils are now in a position to appreciate several important conclusions at which biological science has arrived and which profoundly affect human interests and human thought.

By reproducing some of the experiments and investigations even to a very limited extent of certain well-known biologists, the romance and the significance of their work can be realised.

In the course of this work ideas of unity amid diversity and order amid change must have grown in the pupil and will seek expression in a clear survey of the processes of change and an inquiry into its method. They are, therefore, ready for a wide and rational conception as expressed in the theory of evolution.

Books of biography and travel should be at the disposal of the pupils, as also carefully selected books on modern biological thought. A considerable part of the work will naturally take the form of lecture demonstrations preceding or following relevant practical work on the part of pupils.

The syllabus cannot now be divided into sections of one term each as several topics can be studied concurrently.

1. Study of Moulds. Examination of common organic materials which have become mouldy. Life history of 'mould.' Mode of nutrition. Pure cultures of moulds. Making a garden of moulds. Yeast. Fermentation and bread-making.

2. Study of toad-stools. The main groups of the larger fungi.

3. Study of Bacteria. 'Germs' causing broth to go 'bad.' Germ cultures. Spontaneous generation controversy.

4. Sterilisation of food by heat and by preservatives.

5. Pasteur and the silk-worm disease. Lister and the antiseptic treatment of wounds. Manson and Rose and malaria. Phagocytes and bacteria. Life-saving discoveries of Jenner. Koch, Pasteur, Wright in the treatment of widely spread diseases. Vaccines and anti-toxins.

6. Micro-organisms as scavengers. Fixation of nitrogen. Useful in cheese-making and tanning.

7. Discussion with practical illustration of Symbiosis and Parasitism.

The general theory of evolution. Evidences of evolution. The great steps in evolution. Life and work of Charles Darwin.

Controversy on the subject of the inheritance of acquired characters.

Mendelism: its fundamental principles and results made plain by means of a model.

Man's place in the scheme of things.

Progress in intellectual and practical control.

8. Syllabuses of General Elementary Science.

General science is at present included in the syllabuses of the Oxford and Cambridge Joint Board, the Oxford Local School examination and (under certain conditions) by the Civil Service Examiners. The syllabus of the Oxford and Cambridge Joint Board is here reprinted as an example of what is prescribed for School Certificate candidates.

General Science.

Papers will be set to test the candidates' knowledge of scientific principles and of their application in everyday life, as indicated in the following schedule :—

Section 1. Principles of mechanics, illustrated by falling bodies and by simple machines ; the meaning of mass, weight, force, energy ; the transformations of energy.

The general properties of solids, liquids, and gases ; principles of hydrostatics with practical applications ; outlines of diffusion and surface tension.

Production and sources of heat ; the ideas of temperature and quantity of heat ; effect of heat on matter ; transference of heat. Relation between heat and work as illustrated in the steam engine and the internal combustion engine. Domestic heating and ventilation.

Production and propagation of sound ; pitch, loudness, and quality.

Production and propagation of light ; reflexion, refraction, and dispersion ; colour. The eye and simple optical instruments. Domestic lighting.

Elementary ideas of magnetism. The fundamental experiments of electrostatics. Effects of the electric current. Ohm's law. Current induction with the outlines of its application in the dynamo. Practical applications of electricity in domestic lighting and in the transmission and transformation of energy.

Section 2. The chemistry of air and water and of the elements contained in them. The general laws of chemical combination illustrated by the study of common substances, especially such as have familiar practical applications (*e.g.* chalk, sulphur, salt ; the common acids and alkalis and the salts formed by their interaction ; iron, copper, lead, and their common oxides ; common metallic salts like blue and green vitriols, alum). The explanation of these laws by the atomic theory. The chemistry of combustion ; common forms of fuel ; carbonisation of coal ; outlines of the metallurgy of iron and lead. Oxidation, reduction, bleaching ; catalysis ; solutions ; outline of electrolysis. The relation of the air and its constituents to the life of animals and plants. The fixation of atmospheric nitrogen.

Section 3. The general structure of a vertebrate animal and a flowering plant and the functions of their chief organs. Bacteria and their economic importance. Organisms causing disease. Habits and life-history of common British insects, fish, birds, and mammals, with particular reference to those important to man. The chief constituents of human diet. Simple cases of fermentation and the preservation of food. Elementary hygiene.

The solar system ; stars and nebulæ. Formation and constituents of granite, sandstone, limestone, coal, clay, and slate. Action of rain, wind, frost, ice, rivers, and sea. Fossils and their significance. Stratification, folding, and faulting of rocks.

The formation of soil ; an elementary knowledge of the relation between soils and crops.

There will be no practical examination, but candidates will be expected to show knowledge based on their laboratory work and on their personal observation. Special importance will be attached throughout to considerations of energy.

Candidates are not expected to cover the whole schedule. An ample choice of questions will be given; but candidates will be expected to answer at least one question from each section. In any section of the paper questions may be set having a bearing on the subject-matter of the other sections. Simple numerical calculations will be included. Questions of a biographical nature may be set.

This Syllabus covers a very wide field, and the attention given to different parts of it must be left to individual teachers. There is, however, a wide choice of questions (six out of twenty) in the examination, the only limitation being that one question should be attempted in each section. It is obvious that such a comprehensive course must mean superficial treatment of the subjects. It would be impossible to deal thoroughly with all the sections of the syllabus, and a tendency to be didactic, to ask the pupils to memorise the results rather than to show how those results were obtained, would seem to be unavoidable. This emphasis on facts or principles remembered, rather than on scientific method of studying them, is clearly reflected in the questions set.

There is no practical examination in this subject and no safeguard against ' cramming ' either in the syllabus or in the nature of the questions. It is scarcely too much to say that a candidate could pass the examination without possessing any real knowledge of scientific principles or of observational and experimental methods of study.

The interpretation of the syllabus by the examiners, as shown in the questions set, often shows a misconception of what general elementary science or science of everyday life should signify.

Some of the questions would appear more appropriate in papers in physics or chemistry in School Certificate examinations, and these out of place in a general science examination which should have direct contact with science in everyday life and interest.

The framing of a general science syllabus is no easy task. The present Joint Board Syllabus is suggestive, but what is really needed is practical guidance as to the way in which the various portions of the syllabus are to be treated. With such a wide syllabus it would be impossible to expect a thorough treatment of the whole field. Without an intensive experimental study of a portion of the syllabus typical to some part of it the teaching must be superficial.

A really satisfactory general science syllabus should suggest certain portions to be treated in detail as much for the sake of the scientific method involved in their treatment as for the content of their study. When the method by which these scientific principles were established had been thoroughly worked out, then, and only then, other similar principles might be taken without close or detailed experimental study.

Further, it would be of much assistance to the teacher if the syllabus could be set out in such a way as to show the relation of the various subjects studied to one another.

APPENDIX I.

The Report of the Committee on Science Teaching in Secondary Schools, published in the Report of the Association for 1917, contains so much that is of value and so clearly indicates the spirit which should animate the science teacher to-day, that the present Committee has included a part of that Report below.

Experimental and Descriptive Teaching.

Methods of Instruction.—School instruction in science has, in England, taken the form of individual practical work, laboratory demonstrations, and lectures. In some cases laboratory work is carried on independently of the lectures as regards subjects, while in others it is arranged to run parallel with the theoretical course. Frequently all lessons are given in the laboratory by means of demonstrations and discussions in conjunction with practical work, and there is little lecturing in the usual sense of the term. The basis of the instruction in science in schools where this plan is adopted is the laboratory work, and points are explained or elaborated as they are reached in the practical course.

Another plan is to make the laboratory work ancillary to the lectures, and to regard it as a necessary means of making the pupil understand clearly some points dealt with in them or met with in his reading.

The Unique Value of Laboratory Work.—The primary value of laboratory work in schools is that it brings the pupil into direct contact with reality through his own senses and his own manipulation. In this way only can he learn to see things in their right proportions, to distinguish the essentials of an experiment from the non-essentials, and obtain a firm grasp of a scientific subject. Reading about an experiment, or even seeing an experiment performed, cannot give that security of knowledge which practical contact affords.

Experience shows that when scientific knowledge has been secured by practical work it becomes part of the permanent mental equipment of the pupil. The laboratory is, further, the one place where the pupil learns to acquire first-hand evidence, and to distinguish between that and information obtained verbally or by reading; for this reason also it alone fulfils an essential function in an educational course.

It is possible to use scientific method in the study of history, languages, and other literary subjects, but applied in this way the method can never be accepted as providing the same means of training as laboratory experiment.

Distinction between Manual Training and Experiment.—Although the principle of 'learning by doing' is followed also in courses of manual instruction in which each pupil is impressed with the necessity of relying upon himself, of arranging and carrying out his work in an orderly manner, and of interpreting instructions accurately, and though other advantages may be justly claimed for such work, yet there is always a decided difference between the best scheme of workshop exercises and the experimental work of a rightly arranged experimental course. In the laboratory the development of dexterity and skill is only a secondary consideration, and the attention is fastened on the

answer given by Nature to the question put to it: on the method to be adopted for eliciting the answer, on its significance when obtained, and on the degree of accuracy with which it can be credited.

Preliminary Work to Systematic Instruction in Science.—It is because of the demand thus made on the reasoning powers that in 1910 a Joint Committee of the Mathematical Association and the Association of Public School Science Masters expressed the decided opinion that systematic work in science should not be taken at too early a stage; laying down that 'It is undesirable that either formal physics or chemistry be taught in Preparatory Schools,' and that 'Questions should not be set in formal physics or chemistry at the entrance or entrance scholarship examinations to the Public Schools.' The same Committee, however, recommended that instruction which could be taken at an early stage, in elementary practical measurements of length, area, volume, mass, and density, should be given by the mathematical staff and not by the science staff. Such work can be done in an ordinary class-room with the simplest apparatus, and is thus more easily co-ordinated with the mathematical lessons than when carried on in a room specially devoted to it. The course of measurements, including the use of simple balances, need very seldom exceed twenty hours of practical work; and there can be no doubt that it is of the highest value in giving actuality to the mathematical teaching. Unfortunately, mathematical teachers have often been found to have little sympathy with these practical methods of illustration.

Introductory work in science, whether in preparatory schools or in the lower forms of State-aided secondary schools, should consist of such elementary practical measurements as are referred to above, and of a course intended to interest pupils in natural knowledge and to encourage observations of animal and plant life, earth and sky, and of everyday phenomena manifested in them. Such observations provide material for cultivating the art of expression, and with suitable reading or descriptive lessons will create and foster attention to many aspects of Nature.

Laboratory Methods and Scope.—In laboratory courses two methods of instruction may be distinguished—the subject-method and the problem-method—one or both of which may be followed, or, more often, a combination of the two. The subject-method may be described as a system of impressing fundamental properties and principles upon the minds of pupils by means of a graduated course of experimental exercises. The pupils usually work independently or in pairs, but in some schools the same exercises are performed by a whole class simultaneously as a form of drill, in which case they tend to become of the type of cookery-book recipes rather than that of scientific experiment.

The problem-method aims at suggesting a motive and purpose for every experiment, and thus of creating the spirit of experimental scientific inquiry. It consists in facing a problem, and by means of experiment endeavouring to solve it and related questions which arise during the work. The intention is not, as is sometimes supposed, to make pupils discover for themselves laws and principles previously unknown to them, though to some extent this can be done, but rather to

provide a continuous thread of reasoning for the practical work and a definite purpose for whatever is undertaken. It is obvious that this method demands much more intensive work on the part of the teacher than is required when a prescribed course of exercises is followed; and on this account varying opinions are held as to its practicability and value. What is wanted for the teacher is a laboratory which he has freedom to use exactly when and for whom the teaching requires it, and independently of syllabuses prescribed by external authorities, whether the subject-method with a definite laboratory course is being followed, or the ancillary method in which the experiment to be undertaken by any pupil may arise from his own demand, or be assigned to him to clear up some observed misapprehension, or as a challenge to test his knowledge of what he has been taught, and his resourcefulness, or simply to give the final security of personal practical experience, as already mentioned.

The field which can be surveyed practically in any school course of laboratory work which forms part of a general education is necessarily limited in scope even when the subject-method is followed, and is more so when the object of the work is to encourage the natural spirit of inquiry, and thus to create a perception of the means by which new scientific knowledge is gained. Increased attention to laboratory exercises has, indeed, in recent years often been associated with a very restricted acquaintance with the world of science. The tendency has been to make all the teaching a matter of measurement, to the neglect of the human aspects of the pursuit of natural knowledge. The teaching is, in fact, inclined to be narrow and special rather than broad and catholic. Experimental work should bring appreciation of the precision and methods of scientific inquiry, but, in addition to this instruction, an attempt should be made to cultivate interest in achievements of research outside the school walls.

While, therefore, prime importance must be attached to adequate provision for laboratory work undertaken with the view of imparting a knowledge of experimental methods of inquiry, it is essential that there should also be instruction in the broad principles and results of scientific work which cannot be brought within the limits of a laboratory course. Every pupil should not only receive training in observational and experimental work but should also be given a view of natural knowledge as a whole. The object should be to evoke interest rather than to impart facts or data of science prescribed by an examination syllabus, or even to systematise their rediscovery. There should be no specialisation before the stage of Matriculation has been reached, and whatever instruction is given should be from the point of view of general education.

Human Aspects of Science.—Assuming that laboratory work is commenced at a suitable stage, the question arises as to the best means of presenting the broad view of scientific facts and principles desirable in a modern liberal education. It should not be possible for any pupil to complete a course at any secondary school without a knowledge not only of experimental methods but also of the meaning of common natural phenomena. Much of this knowledge can be given, and is being given, to an increasing extent, in connection with the teaching of

geography; but in any case descriptive lessons are required in which the aim should be to impart broad ideas, and promote interest in Nature rather than to train in practical methods applied to a limited field.

It is desirable also, by means of general lectures, discussions, or reading, to introduce into the teaching some account of the main achievements of science and of the methods by which they have been attained. Science must not be considered merely as a burden of material fact and precise principle which needs a special type of mind to bear it. There should be more of the spirit, and less of the valley of dry bones, if science is to be of living interest, either during school life or afterwards. Everyone should be given the opportunity of knowing something of the lives and work of such men as Galileo and Newton, Faraday and Kelvin, Pasteur and Lister, Darwin and Mendel, and many other pioneers of science. One way of doing this is by lessons on the history of science, biographies of discoverers, with studies of their successes and failures, and outlines of the main road along which natural knowledge has advanced. It would be far better, from the point of view of general education, to introduce courses of this kind, intended to direct attention and stimulate interest in scientific greatness and its relation to modern life, than to limit the teaching to dehumanised material of physics and chemistry which leaves but little impression upon the minds of boys if seen only 'in disconnection, dull and spiritless.'

Under existing conditions, which are largely controlled by prescribed syllabuses and external examinations, there is little opportunity for teachers to direct attention to the useful applications of science on one hand, or on the other to awaken interest in the solution of the mysteries which surround us, though this could be done incidentally in connection with lectures or practical work if the present pressure were removed.

History and biography enable a comprehensive view of science to be constructed which cannot be obtained by laboratory work. They supply a solvent of that artificial barrier between literary studies and science which a school time-table usually sets up. In the study of hydrostatics, heat, current electricity, optics, and inorganic chemistry, the attention which has been given to laboratory work has succeeded in developing the powers of doing and describing. The weak points have been insufficient attention to the broader aspects and to scientific discovery and invention as human achievements, and failure to connect school work with the big applications of science by which mankind is benefiting. The study of optics is seldom pursued to a useful point, and in the teaching of mechanics there are more failures than in other science subjects. The time-table is particularly overcrowded during the last two years in the State-aided secondary schools; the work is over-compressed, and the philosophical aspects cannot, therefore, be presented effectively. The extension of the normal leaving age to seventeen years would have a valuable effect in raising the potential standard of scientific knowledge, and in spreading intelligent appreciation of science throughout the country.

At present, as instruction in science proceeds in the school, there is a tendency for it to become detached from the facts and affairs of life, by which alone stimulus and interest can be secured. It is important that

every opportunity should be taken to counteract this tendency by descriptive lessons in which everyday phenomena are explained and the utility of discovery and invention is illustrated.

Domestic science and hygiene are frequently introduced into girls' schools with the object of effecting a link between science and the experience of everyday life. It must be pointed out, however, that such courses are incoherent and of little value unless science or domesticity is the definite objective. If the scientific aim predominates, the course can be made to give a good training in elementary experimental science and should afford a useful background to later practical study of domestic arts. If domesticity is dominant, the work cannot be accepted as an effective substitute for a proper science course.

Summary.

The observational work by which the study of science should begin opens the eyes of the pupils and may be used to train them in the correct expression of thought and of accurate description. The practical measurements in the class-room have for their object the fixing of ideas met with in the mathematical teaching. Every pupil should undergo a course of training in experimental scientific inquiry as a part of his general education up to a certain stage, after which the laboratory work may become specialised and be used to supply facts which may be a basis for more advanced work or to prepare pupils for scientific or industrial careers.

At suitable stages, when pupils are capable of taking intelligent interest in the knowledge presented, there should be courses of descriptive lessons and reading broad enough to appeal to all minds and to give a general view of natural facts and principles not limited to the range of any laboratory course or detailed lecture instruction, and differing from them by being extensive instead of intensive.

Finally, the aims of the teaching of science may be stated to be: (1) To train the powers of accurate observation of natural facts and phenomena and of clear description of what is observed; (2) To impart a knowledge of the method of experimental inquiry which distinguishes modern science from the philosophy of earlier times, and by which advance is secured; (3) To provide a broad basis of fact as to man's environment and his relation to it; (4) To give an acquaintance with scientific words and ideas now common in progressive life and thought.

APPENDIX II.

Typical Science Courses.

Experience has shown that the most useful function a committee on science teaching can perform is to present schemes of work which can be carried out practically. Examples of the influence of such schemes are afforded by the Reports on Teaching Chemistry presented by Committees at Newcastle-upon-Tyne in 1889 and Leeds 1890, the Report on the Teaching of Elementary Mathematics presented at the Belfast meeting in 1902, and the Report on Science Teaching in Secondary Schools published in the Report of the Association for 1917. The effects of these Reports have been so beneficial and far-reaching that the present Committee is hopeful that the specimen courses here submitted[6] will have a like influence upon science teaching. It is not suggested that the schemes should be prescribed for any particular schools, but rather that they should be considered as examples of courses which have been proved successful.

I.—Science for all in a Public School.

By Archer Vassall, Harrow School.

I. A scheme of work in science at a Public School must allow for the special features which obtain normally there as compared with the conditions at many other secondary schools. The peculiar features which affect the science scheme are that (1) practically all the boys come from a particular class of preparatory school; (2) their age at entrance is just under fourteen; (3) they may join the school over a wide range of Forms; (4) they may remain till they are eighteen and a half years old.

The terminology of Forms varies so much at different schools that it is convenient to regard the school as divided into five blocks, A, B, C, D, E—A containing the upper school, B and C the middle school, and D and E the lowest Forms. The ablest boys are expected to join the school in C, the less able in D, and the worst (intellectually) in E.

Roughly, the majority of Block A corresponds to a post-matriculation stage, and the rest to a pre-matriculation stage. The latter are entirely concerned with their general education, but the former in the lower forms of Block A are beginning a semi-specialisation in groups of subjects which will culminate at the top in completely specialised or even vocationalised work.

'Science for All' constitutes an essential part of general education; therefore it must be compulsory where it will embrace the greatest number of boys for a sufficient portion of their time-table. This is best achieved by making it compulsory in Block C and Upper D, equally for Classical and Modern sides when these exist in this part of the school. There is no difficulty about this or the other suggestions put forward when the ultimate school authority is sympathetic; they are possible at any Public School, but they may not be desired by those in power.

Compulsory science in C and Upper D, however, may not secure the ablest boys for a sufficient length of time, as they may pass into B very quickly. This can be corrected by making science compulsory for a minimum number of terms—*i.e.* a boy passing quickly into B must continue science in B until he has completed the science comprised in the general education.

A. Science in A will comprise science specialists.

B. Science in B should be alternative with other subjects for boys who have completed the compulsory 'Science for All.' The boys taking science will then have completed the general courses and will begin a formal study of science. They should give not less than eight hours per week to the subject.

The alternative subjects for those boys in B who do not take science must be decided by each school for itself. There is obviously one main consideration for a

[6] Reprinted from the 1917 Report with modification suggested by the writers.

boy of scientific aptitude in deciding whether he will take science or the alternative subjects in B. The other subjects *can* be studied by securing a competent teacher, whether in the holidays or in 'out-of-school' hours in term-time. But for science a laboratory is essential, and term-time at school will be for many boys their one and only opportunity of doing experimental work in a laboratory.

Thus the science in B comprises (1) boys giving eight hours per week to the subject, (2) boys completing 'Science for All.'

C and Upper D.—Science is compulsory for a minimum of five hours in school and one hour's preparation per week for six terms—or its equivalent. Boys should be re-graded for science according to their progress and ability.

Lower D.—The work consists of self-contained courses, emphasising the human and practical sides of the subject. These boys need not be re-graded.

E.—The work should be co-ordinated with similar work undertaken at preparatory schools such as Nature Study, &c.

II. *Aims of the Compulsory Science.*

1. Training in scientific method by experimental investigation.
2. Conveying useful information and fixing it by practical exercises.
3. Arousing interest and discovering special aptitude for science.
4. Emphasising the human aspect of the work as much as possible by using daily-life phenomena, practical applications, machines, agricultural processes, &c., as the material wherever possible.

III. *Freedom of the Teacher.*

Within the above principles complete freedom should be left to the teacher in accordance with his interests and opportunities. He should arrange his own courses, syllabuses, &c., decide what material he employs for any of the above objects, and whether he achieves them by 'object,' 'subject,' 'problem,' or any other method.

IV. The 'Science for All' should be carefully co-ordinated with the other work of the school—more especially the mathematics and geography. Where essential work is not adequately dealt with under these subjects, it must be included in the science course—*e.g.*, elementary mechanics with sufficient practical work, and elementary physiography.

V. Every school should be free to create its own syllabuses and treatment of them, provided the two vital essentials of conducting experimental investigations and emphasising the human aspects of the subject are attained.

Some examples are here given—they are not prescribed or even recommended but simply selected as illustrating the above points.

A. A course taken by boys in Lower D as an introduction to the experimental method.

Experimental Investigation of Chalk.

Experiments to be done by the boys themselves in the laboratory, with occasional lecture demonstrations and discussions to connect up the results arrived at and for those experiments which are unsuitable for the boys to perform at this stage, such as the electrolysis of fused calcium chloride.

Examine chalk, notice its physical properties, and find out if it is soluble in water. Is it an element or a compound? Effect of heat on it. Does it change in weight when heated?

Collect the gas given off on heating chalk in a silica tube. Study the properties of this gas. The same gas is given off when chalk is treated with acids, and this is a more convenient way of making it.

The gas will not support the combustion of most substances. Try if burning phosphorus and magnesium will continue to burn the gas. The latter continues to burn with a spluttering noise. The residue left is composed of a white substance, similar to the ash left when magnesium burns in air or oxygen and black specks.

This white ash is a compound of magnesium and oxygen, therefore the gas contains oxygen. Separate the black specks from the white ash by treating the whole ash with hydrochloric acid; wash with water—collect and dry. The

black stuff looks like charcoal. It burns in air or oxygen and forms a gas which turns lime-water milky. But carbon burns in air and forms the same gas. Therefore the black specks are carbon, and the gas from the chalk is composed of carbon and oxygen. We call it carbon dioxide or carbonic acid gas.

Return to the residue left when all the gas has been driven off by heating chalk. It is a white substance. Try the action of water on it. Is it soluble in water? Shake it up with water filter, and blow air from the lungs into the clear filtrate. It turns milky. It is lime-water. Excursions here into the slaking of quicklime, and the uses of slaked lime. Demonstration of the preparation of calcium by the electrolysis of fused calcium chloride.

Burn some of the calcium obtained in oxygen and prove that the white substance obtained is identical with quicklime. Therefore quicklime is a compound of calcium and oxygen.

$$\text{Chalk} \quad . \quad . \begin{cases} \text{Gas} \quad . \quad . \quad . \quad . \quad . \begin{cases} \text{Carbon} \\ \text{Oxygen} \end{cases} \\ \text{Quicklime} \quad . \quad . \quad . \quad . \begin{cases} \text{Calcium} \\ \text{Oxygen} \end{cases} \end{cases}$$

Many objects are suitable for such courses—e.g., *the candle, common salt, hæmatite, &c.*

B. Some teachers prefer to take the work as a problem rather than as subjects. Much of the conventional 'subject' matter naturally arises when this treatment is adopted, and each suitable occasion for experimental inquiries germane to the general inquiry is taken. Moreover, the manipulation and laboratory practice arise as a necessity in the course of the investigation and the various subjects are correlated. Of course, both these ends should be attained whatever the method employed. But in 'subjects' there is a strong temptation to take elementary practice as an end in itself; something to be 'got through.' There are few things more unattractive and dehumanised than such courses, which seem absolutely pointless to the boy. For example, he does not feel the need of accurate weighing, determination of density, specific gravity, &c., and he has no mental picture of any problem on which such matters bear. When they are not done as 'ends in themselves,' but taken as they occur as necessary machinery in the course of an investigation, their apparent pointlessness disappears, and the boy is at least reconciled to them as necessary evils.

In 'subject' courses also so much time is often taken over the laws and their establishment that the applications and machines are never reached

This result is avoided if the course starts from a machine and is then left to create itself under the direction of the teacher. Suggestion and discussion at the end of a period as to the next thing to 'go for' result in some questions being simply answered, some discarded by consent for various reasons, whilst others are dealt with experimentally by the boys themselves or by demonstration lectures.

Thus the properties of water can be investigated as so many geological, biological, chemical, and physical 'subjects.' Or they can be correlated into one problem course beginning, for instance, with the hydraulic press and then developed as above. Starting from the press, there immediately arise transmission of pressure, fluids and solids, principles of machines, work and force. Various pumps follow, leading directly to air pressure and experimental investigation into it by the boys themselves. Barometers, pressure on divers, dams, lock-gates, together with deep-sea sounding, chalk, sand, clay, and Artesian wells provide the humanising element. Flotation follows with Archimedes' Principle, buoyancy, &c.; where there is a school bathing-place it is best worked out there practically with a raft, a raft of casks, and a weighing machine.

Sea-water's buoyancy leads on to its properties, solution of solids, crystallisation and solution—all arising out of the problem, instead of as pointless and seemingly useless preliminaries necessary for some future unknown work of which the boy is ignorant. Solution of air and its influence on fish, &c., lead to Harrogate water, soda-water, sparkling wines, bread or sugar in a lemon squash.

Carbon dioxide suggests its preparation and properties, respiration, breathing, burning, and decay; and so nitrates and manures on the one hand, and

limestone, with limestone caverns, stalactites, hard and soft water, water supply, good and bad water on the other. Organic matter in water and its purification can extend as far into typhoid, diphtheria, bacteria, infection, inoculation, vaccination, milk, &c., as the teacher desires.

The compounds and mixtures reached as above lead to inquiries as to the nature of water and suitable chemical investigations, which are followed naturally by more physical considerations—its change of volume on becoming steam, pressure in boilers, and the steam-engine with B.H.P., ending in the boys determining their own B.H.P. The source of the energy being heat, the rate at which the gas-burners supply heat can be determined, and so the unit of heat is reached, together with the mechanical equivalent (Callender's Apparatus) and the thermal efficiency of the engine. The effect of pressure on the boiling-point introduces evaporation and boiling, together with rain, dew, and hydrometers.

They are now ready for another change of state, so formation of ice, bursting water-pipes, disintegration of soil, icebergs, deep sea and life in the abyss, provide one line, whilst latent-heat cooling by evaporation, freezing machines, and liquefaction of gases afford another.

C. The majority of schools, however, find the 'subject' method more convenient. Except perhaps in the matter of correlation, the disadvantages mentioned above can be avoided if it is realised that the introduction of the human element and experimental investigations should be the main features. Since this is the only science work many of these boys will get, the object is not to clear the way for a future study of science, but to provide self-contained work complete in itself. This means a broad landscape as the general picture, with detailed work in particular fields to provide the experimental inquiries. The geographical work of the school may provide it; but, if not, an introductory course should present a broad view of the Universe, the position of the earth in it, the changes which the earth undergoes by volcanic and other action, as well as some of the usual physical and chemical properties of the atmosphere.

Forms of life on the earth can be begun here, but not taken very far, as much of this biological work is helped by some physical and chemical understanding. It is a disadvantage where the 'subject' method is employed to get the biological work ahead of this ancillary knowledge. The most satisfactory results are attained by retaining a portion of the time each week for biological work throughout the six terms. Different stages in it are then reached *pari passu* with the progress in physics and chemistry. The final stages are attacked with the more adult and trained grip, following four or five terms' work at science. At the least the biological work should comprise the life of a plant, simple agriculture, crops, fixation of nitrogen, manures; an excellent experimental investigation into the overthrow of the humus theory by Ingenhauss can be carried out, together with other practical work. In the botanical section there should come an introduction to the work of Darwin, Mendel, Pasteur, and others. In fact, this acquaintance with the foremost men in the history of scientific knowledge should be included in each subject. Material full of human interest is provided by coal, fungi, yeast and its uses, bacteria, ferments and fermentation, with many examples, pasteurisation, tinned and bottled goods, ptomaines, infection, refrigeration, and so on. University framers of a syllabus for the average boy and external examiners revel in the action of sulphuric acid on copper and similar phenomena as an educational medium; the vast majority of candidates pass through life without ever meeting such an action outside the academic atmosphere of the class-room, any more than they meet the Greek particles. Bread, cheese, and beer are apparently beneath the consideration of academic science specialists. None the less, fermentation, moulds, bacteria in hay infusions, &c., are unequalled as a material for experimental investigation and instilling a true scientific habit.

In the same way in zoology, the work of Jenner, Lister, Metchnikoff, and other great discoverers should be brought out in connexion with simple hygiene. This course should also include reference to microscopic animal life and its effect on the earth's surface (*e.g.*, chalk and flint), respiration, blood circulation, malaria, sleeping sickness, or to useful natural products within the Empire, and some simple agriculture.

The other subject courses are more familiar. It is only necessary to direct attention to the special human features of the work and to give one or two examples of experimental investigations. Thus, the hydrostatics can be based on a machine and involve consideration of other familiar applications in addition to those already mentioned in *A*, such as pulleys, jacks, balloons, siphons, and turbines. If the mathematical work of the school does not comprise them, then falling bodies, Newton, &c., Galileo's disproof of Aristotle should be taken here. It is important that typical instances of the overthrow of a generally accepted theory, as well as the work of some of the great pioneers, should be familiar. The elementary chemistry affords excellent material for this, as well as for experimental investigation. For example, in the consideration of combustion and the phlogistic theory, let the boys perform the six following experiments :

1. Does magnesium really lose weight when burnt? Gain in weight may be due to crucible, therefore
2. Does crucible gain in weight? Perhaps the air is concerned in the increase, therefore
3. Burn phosphorus in bell-jar over water. One-fifth of air active; rest, inactive. What has become of the phosphorus and the active constituent?
4. Test water with litmus. Dissolve some phosphorus pentoxide in water and add litmus.
5. Burn phosphorus in a weighed round-bottomed flask with stopper and valve. (*a*) Heat has no weight, (*b*) conservation of mass, (*c*) gain in weight on opening valve shows that air has been used.
6. Burn candle and catch products; determine gain in weight.
7. Demonstration with oxygen and nitrogen to show properties of active and inactive constituents.
8. Lecture on history and overthrow of phlogistic theory.

The study of the atmosphere and the chemistry of daily life should form the basis of the whole chemical course in this general science. In connexion with flame, the simpler hydrocarbons and their combustion should be dealt with, and the artificial distinction of 'organic' chemistry should not preclude the average boy from dealing with the petroleum industry, coal-tar products, benzene, phenol, toluene, aniline dyes and mordants, sugar, alcohol and its uses, oils, fats, soaps and glycerine, nitroglycerine, and other explosives.

The subject of heat probably provides the ideal experimental investigation in heat quantity—*e.g.* :

1. Heat 500 grammes and 1,000 grammes of water over a steady flame; plot graph of time and temperature for each.
2. Mix 500 grammes of hot water with 500 grammes of cold water.
3. Mix 500 grammes of hot water with 1,000 grammes of cold water.
4. Mix 1,000 grammes of various cold metals with 500 grammes of hot water.
5. Mix 100 grammes of hot water with 200 grammes of cold mercury.
6. Make a cooling curve for, say, phenol.
7. Heat ice steadily until the water formed boils—make a temperature-time curve.
8. More accurate determination of specific heat and latent heat.

The rest of the work should be associated with practical applications as much as possible. Out of the small total time available for science, it is an unjustifiable waste to devote part to filling and sealing thermometers, coefficients of expansion, &c., beloved of the text-book and the examiner. All of this type of work is very necessary for those who are going to continue the study of science, but perfectly useless for that majority which will not do so. Men of science are prepared to use a watch without having made one. Why should not the 'general science' pupil use a thermometer without first making it? With the saving of time thus effected, there is plenty available for work which really interests them, such as heat values of fuels, heat and work, work and power, horse-power, B.H.P. of an engine, steam-engine, energy losses, I.H.P. efficiency, and so on.

In the course on light the simplest treatment of rectilinear propagations, candle-power, intensity, photometers, plane mirrors, laws of reflection and refraction,

images, internal reflection, and dispersions will allow the pupil to deal with what he 'wants to know about'—viz., searchlights, prisms, lenses, the eye, spectacles, magnifying glasses, telescopes, microscopes, rainbows, the spectrum, and fluorescence.

In the subject of sound, waves and frequency are practically all the average boy requires in addition to the ear, Doppler effect, siren, gramophones, and Claxon horn. In all these he is interested.

After magnetism, electro-magnets, and telegraphs, the boy reaches his electrical paradise. The effects of a current and its measurements by any of these effects, B.O.T. unit of current, ammeters, voltmeters, microphone, telephone, dynamo, magnets, motor, *X*-rays, wireless telegraphy, electrical energy and power, Watt lamps, wiring of houses—these abolish all need of punishment for lack of industry in trying to understand physical laws; indeed, they help that understanding.

In this scheme emphasis has been laid especially on those aspects of the work which make the subject alive and personal; this treatment does not exclude a grasp of those elementary laws with which an educated man should be familiar. It only insists on associating such laws with their practical applications. This generalised science scheme for those boys who are not pursuing the subject any further has been evolved during ten years at a school. In arriving at its present stage, which is far from perfect, some golden rules have been applied :

1. Make sure of the landscape; do not start the boy on a niggling bit of formal science.

2. Exclude rigorously any work, practical or otherwise, which is not worth doing for itself.

3. Some work is worth doing because it is valuable educationally—*e.g.*, experimental investigations. Other work is worth doing not only because it has educational value; it also concerns itself with matters which occur in the average life of an educated citizen who is not actively concerned with a scientific career.

4. Some work is only contributory to the further study of science beyond what is necessary for a general education. This work is an unjustifiable waste of time for those boys who will never study science further.

5. Be suspicious of anything which occurs in any existing examination syllabus. It is usually there for the convenience of the examiner, or because it is contributory to the formal study of science.

6. Consider the conditions of the school and the personal equation of the teachers rather than examinations in drawing up a syllabus for the average boy.

His need is to understand (1) the multifarious ways in which the results of scientific investigation affect his daily life, (2) the experimental methods by which the natural phenomena of daily life are being investigated, (3) whilst knowing the value of an expert, none the less to be confident and resourceful within his own limitations.

II. Science in a Public School.

By F. W. Sanderson, late Headmaster, Oundle School.

The course here outlined indicates the kind of work which may be done in schools by boys below the age at which specialising begins. This age depends upon the type of school and the leaving age, and varies with the tastes and capacities of individual boys. In a Public School where the leaving age is nineteen the specialising age is about seventeen years. The course presented applies to boys below the age of seventeen—*i.e.*, to boys of the Preparatory School age, and to the lower and middle forms of the Public School. The methods proposed are based on the belief that the early stages of science teaching may be taken through applied science. Science, like history, may with advantage be read backwards. Pure science and pure mathematics may be taught in parallel with applied science, as the grammar of the science, but it will be found for the most part that the amount of pure science that the average boy can understand will be included in the applied work.

A claim is therefore made for the inclusion of applied science within the general science curriculum of a school. There is some reason for this now, when so many of the applications of science come within the daily life of the people. It is a well-known saying that a motor-bicycle has taught a boy more of true dynamics than he has ever learnt from the Laws of Motion. However this may be, it is obviously a wise educational principle to base teaching on all that is now common knowledge.

It must be confessed that much of the pure science which comes within an elementary course is better left to a later age. Experiments on Boyle's law, and the other law of gases; the discussion of the laws of motion; complex questions on specific heats, should be reserved for the specialising age. This is following in the wake of the reforms in the teaching of geometry. Applied science actually simplifies the problems. The steam-engine is a good example, as is shown in many parts of Perry's 'Steam Engine.' Here is material for an elementary course on heat, and a source for easy direct calculations of practical importance. Moreover, the method is informative, and gives a working knowledge of the engine which will stand in good stead.

A further claim is made. This form of science teaching is stimulating and arresting, and gives the boy plenty to do and much to think about. It arouses interest, develops intelligence, and promotes catholicity of taste. Teachers will find that the application of science, and all that may be called the romance of science, are alive with possibilities for the education of the young in everything connoted under the words Culture, the Humanities, and Art. Much depends upon the faith of the teacher, but no one can study the life and works of a great discoverer without finding himself within a realm of art. There is abundance of evidence for this in the works of those masters of science who to their creative faculties have added the literary art. But the science art remains even without its literary expression, and men and women may learn to appreciate the art as they appreciate music and painting, though they have no skill as musicians or painters.

Science in a General School Course.

There are many considerations why the science in a general course, especially for those boys who will not specialise in science, should not be restricted to the elementary syllabuses. Many of the syllabuses and elementary text-books dwell upon principles which now form the grammar of science, whilst the larger developments of modern days are not touched upon. 'Science for all' does not mean this kind of science—grammar without the books. Except in the hands of a good teacher such work may have little of inspiration, and in a general course inspiration is everything. A claim is therefore made for a kind of science teaching which at first sight may be thought specialising and technical. In sympathetic hands specialising need not be feared.

The branches of science which may be included in a general course for schools are indicated below. These can be organised according to the ages of the boys. The methods of teaching which they imply will be especially valuable for young boys of the Preparatory School age. In his early years the small boy can wander through these fields of knowledge. He can learn to handle tools in an engineering shop; he can work with motors and other machines; he can open his eyes in the romance of physics, chemistry, and biology; and he can practise weighing and measuring in his class-room. The older boys, from fourteen to seventeen, will go over the same ground, but on a higher plane, and will in the later stages acquire a working knowledge of applied science.

The following are the subjects :—(1) Workshops; (2) 'Romance of Science,' including Astronomy; (3) Experiments on the Use of Machines; (4) Biology; (5) Chemistry; (6) Physical Measurements, and, at a later stage, (7) Applied and Pure Science.

1. *Workshop Practice.*—Belief in the value of a continuous workshop training must be the excuse for the space here given to the organisation of shops. In the first place, the shops must be on a scale which will employ a class of

twenty-five boys effectively. They must form a small manufactory, and have an engineering machine shop, a carpenter's or patternmaker's shop, a smithy and foundry of some size. These conditions are essential for true work. Smaller shops tend to be of an amateur character, and only a few boys can get the best out of them. Workshops to be effective must be on a large scale. It is seriously necessary that such shops should be established, not for Public Schools only, but for Secondary and Elementary Schools, nor should expense stand in the way. Such shops could be made self-supporting. Schools should be able to turn out good craftsmen as leaders or workers in the industrial life of the country, and the training can be given in schools better than in works. In works, unfortunately, much of what is good is spoilt by the spirit which competition and the conflict of capital and labour engender. Boys sent out from the schools can not only be made good craftsmen, but they can also be inspired with ambition to rise to high standards of skill, and to have a deep insight into the significance of their work. Enthusiasts believe that vocational teaching is capable of giving the highest training for life.

There are two methods of working shops. Under one system boys make things for themselves, and may follow some hobby. This is the individualistic principle, and is the only one possible in small shops. The other system is to organise the shops on manufacturing or co-operative lines. The war has given the opportunity of doing this more effectively than before, and the possibility for true education of this kind of working has been discovered. Co-operative work involves repetition work, and there are many excellences in this repetition. In shops of fair size a variety of work can be contracted for, and this work will fill several types of machines, such as the lathe, drilling, planing, milling, slotting, grinding machines. A contract of the kind now being given for munition work provides work both rough and fine, so that all boys can be occupied; and no boy need be kept too long at the same class of work. This work gives opportunities for boys who do not distinguish themselves in other parts of the school; and they can therefore take a higher place among their fellows, as well as gain self-respect and reliance.

The following are some influences of workshop training:—

(*a*) One chief characteristic is the attitude of mind which is fostered by the shops. This is all towards attention and creativeness. Workshops are places where things are made, and the objective is to make something. A boy goes there to do, and not to learn. His attention is fixed on his work. Determination to do the work in front of him and to acquire skill and practice is the chief aim. This spirit towards work is transferred to the class-room and changes the boy's view-point there. The influence is infectious, and keeps alive the spirit of creativeness.

(*b*) Another effect of the workshops is to develop craftsmanship. A boy acquires the virtues of a first-class workman. He becomes deft with his tools, learns to be patient, careful, accurate, inventive. He acquires the power of construction and of initiative.

(*c*) In a workshop a boy lives in the atmosphere of mechanics and physics, and is continually either making or reading engineering drawings. He has the chance to acquire a mechanical sense and to learn by intuition the significance of force, speed, acceleration, rotation. He has many opportunities of using measuring instruments, and of making physical measurements. He learns machine drawing, and mechanical drawing is becoming daily of more interest and importance—even to the non-specialist. A drawing-office can be made the very heart of mathematical teaching, as it is the centre of engineering works. Very young boys can be effectively employed in a drawing-office, and they learn in a practical way many of the principles of geometry.

(*d*) Incidentally, boys are given a vocational teaching. There are many professions where a knowledge of technical work is essential. A craftsman's knowledge is of value to barristers, solicitors, clergymen, social workers, landowners, and all whose aim in life is 'to do.'

2. *Romance of Science.*—It is about fifty years ago since science was introduced into the Public Schools. This was done largely by the influence of Huxley and Tyndall, and the form it first took was that of demonstration

lectures. The object in view was to interest the sons of the governing classes in the astonishing discoveries that were being made, and to inspire them with the love of science. Many a boy must have found inspiration in these lectures, but for the great mass of boys the results on the whole were not successful, and the chief reason for this is that boys like to do things for themselves rather than watch other people doing them. They want a share in the doing, and to investigate for themselves. Some years later a change came, and the lecture theatre gave place to the laboratory. Boys were set to work for themselves. The heuristic method was emphasised, and courses were arranged in physical measurements, chemical experiments, and nature study. This method is now well established in schools, and forms the basis of most schemes of study and syllabuses for examinations. It would seem, however, that this necessary laboratory work has driven the more inspiring experiments into the background. At the moment it is important to return to the lecture theatre, to come into contact again with striking experiments, the history and development of discoveries, the lives of the great; in fact, to the romance of science. It is the romance of science which contains within itself the great inspiration, and the first duty of the teacher is to inspire boys with an awakening love of the natural world and bring them to the verge of knowledge where lies the mystery.

There are difficulties in the way of holding the balance between the two methods. Romance of science opens out ideals, whilst physical measurement trains for exact work in investigation. Both aims are necessary. The regular laboratory work should therefore go on *pari passu* with any system of demonstration experiments.

A suggestion may be made for the 'Romance of Science' experiments. Groups of Forms, Senior, Junior, or Preparatory, may be organised to prepare an exhibition of experiments and demonstrations. The masters apportion the work to groups of boys, and these groups prepare the exhibits and experiments. They make the diagrams and sketches required, write up explanatory and historical matter, work the experiments, and explain the exhibits. Such exhibitions can be left in working order for the instruction of the science classes. Mechanics, physics, chemistry, biology, provide a host of such exhibits. Junior Forms may set up a series of well-known historical experiments; Senior boys may be encouraged to illustrate modern advances. There are many books amongst the classics in science which will form the basis of such an exhibition. The 'Heat and Sound' of Tyndall; Ball's 'Experimental Mechanics,' or Perry's 'Steam Engine'; Thompson's 'Light: Visible and Invisible'; Wright on 'Projection,' Boys's 'Soap Bubbles' or Perry's 'Tops'; Worthington's 'Splash of a Drop'; Lodge's 'Pioneers of Science.' There are fascinating experiments on the discharge through rarefied gases, with radium and X-rays, vibrating springs, liquid air, rotating bodies; many chemical experiments and biological exhibits. Lectures or exhibits can be prepared to illustrate the life and works of a great investigator—men like Faraday, Dalton, Darwin, Pasteur. Original papers can in this way be brought before the school. If the school possesses plenty of space, many exhibits can be on view permanently.

A valuable addition to a school, or combination of schools, is a museum of history, where developments in art and science may be illustrated. In the museum there should be a gallery of the world's workers and pioneers, that something may be learnt of their lives and what they looked like. Here may be shown such things as the genealogical tree of the aeroplane, the uprising of biology, the influence of science in the social life, and so on.

3. *Experiments Based on the Use of Machinery.*—The teacher of science has now at his command a large number of machines, tools, and measuring instruments. The use of these for their normal purpose, or the testing of them, affords a striking method of introducing young boys to the principles of science, and gives good exercise in mathematics. Experiments can be arranged for young boys of the Preparatory or Elementary School age with engines, dynamos, measuring instruments, testing machines, &c., to infuse the spirit of science and lay a foundation of information upon which to build at a later stage. A few of the experiments can be given as examples: (1) To find the horse-power and efficiency of a motor; (2) to run a test of a gas-engine—B.H.P., consumption of gas, I.H.P., working out of cards, efficiency; (3) steam-engine

with varying loads and cut-offs; (4) experiments with voltmeters and ammeters; (5) testing strength of material. Very young boys can with advantage be brought to this kind of work, but the teacher must be content to sow in faith. He must sow the seed and wait for the fruit.

The calculations required in experiments of this kind will suggest their extension into the mathematical class-room. The mathematical class-room may be used as an office, for it is a useful thing in all parts of the school, especially the lower half, to give practice in working out a series of continuous calculations. Data may be given drawn from an engine test, from the working of a crank shaft, from agricultural operations, trench fire, artillery maps, food rations, measuring velocity of wind; and the class may be set to work out the calculations required. It is useful for the master to talk round the problem for a few minutes before starting work. If many calculations are required, the work can be divided up amongst the boys. The results can be stated not as an answer, but in the form of a written report. This form of teaching considerably extends the range of mathematics which may be covered in the early years, and boys of fourteen or fifteen may be introduced through it to the study of the calculus and co-ordinate geometry.

4. *Biology.*—The importance of biology in a scheme of general education cannot be overstated. It is the science which very closely touches the life of the nation, and its economic value is found in all directions. Every branch of knowledge in the years to come will be influenced by the study of biology, and the humane studies in history, economics, sociology will be re-written under the same.

Biology should be an integral part of school studies, and take its place by the side of languages and mathematics. In the early years it should be taught to all, and later to a group of specialists.

The following brief notes on equipment may be useful:—

The neighbourhood can provide material for observation and study, but in addition to this there are needed for experiment and observation some or all of the following: (*a*) Biological or botanical garden; if possible, a small experimental farm. The gardens may contain natural-order beds, herbaceous border, Alpine garden, pond, marsh, seashore, climbing plants, &c. (*b*) Experimental plots. (*c*) Laboratory and museum; in these, aquaria, breeding cages for life-history of insects, terraria, vivaria, insect incubators, &c.; microscopes and lenses, &c.

5. *Chemistry.*—Here again the work should be almost entirely experimental, enlarged by demonstration. Much help can be given by the boys who are specialising in chemistry. Much of the work should be of a quantitative character, and this aspect should develop side by side with the qualitative nature of the same. Many points of contact with the order of Nature in everyday life will occur, and the utmost should be made of these in correlation with biology and physics. None but exact scientific types of apparatus should be used where there exists no valid reason to the contrary. As an example, a boy should, after his discovery of the composition of the atmosphere, make an exact determination of the properties of oxygen by Hempel's or some similar apparatus. A muffle furnace should be in the laboratory for use in metallurgical work.

6. *Applied Science.*—It is strongly recommended as an alternative course in the later years of the general school teaching—*i.e.*, from the ages of 15½ to 17 years—that the ordinary mechanics and physics should be replaced by a careful experimental study of applied mechanics, heat, and electricity. In the reorganisation of examinations it is to be hoped that an examination on these subjects will be included in the leaving certificate, and wherever possible a practical examination be held on the experiments which belong to a well-equipped engineering laboratory. A syllabus based on these lines is now adopted by the Admiralty for two of the papers of the Direct Entry examination.

III. Scheme of Science Work for an Urban Secondary School for Boys.

By T. Percy Nunn.[7]

[Professor of Education in the University of London; formerly Chief Science and Mathematics Master in the William Ellis School.]

The following scheme is drawn up for a four years' course (ages twelve to sixteen) in an urban Secondary School for boys. The work of each year is divided into two sections—' biological ' and ' physical.' The proportion of time assigned to biology decreases from more than a half in the first year to a fifth or less in the last year, with a corresponding increase in the relative importance of the physical section. It is assumed that about five hours a week are assigned to science teaching in each year, and the great bulk of the matter here set down is to be dealt with in this time. It may, however, be taken for granted that in a well-organised school there will be close co-ordination between the teaching of science and the teaching of mathematics and geography. It has seemed advisable, therefore, to include in the science syllabus the corresponding programme of work in mechanics and geology, though much of the former, and possibly the whole of the latter, may and should be taught in lessons assigned to the teachers of mathematics and geography as integral parts of their work.

In a condensed outline it is not possible to give a full programme of the practical work to be done by the boys, or to distinguish those topics that are more suitable for demonstration. It is to be understood that the course is intended to throw into clear relief the fundamental ideas and results of science, and to give the pupil a real, if rudimentary, acquaintance with the true character of scientific inquiry. To attain these ends the work will often be ' heuristic ' in character and as often take the form of lecture-discussions between teacher and class, preceded, accompanied, and followed by experimental work. Occasional practical exercises of the ' drill ' type will be necessary to give the pupil a sound grasp of a principle or a method, but one of the presuppositions underlying the scheme is that technical exercises of this kind divorced from the development of a definite scientific argument have comparatively little value and have received too much emphasis in the past.

First Year.

[In Section I. the work is arranged in accordance with the seasonal sequence. In Section II. the work in astronomy should also run throughout the year side by side with the other subjects.]

I. *Biological Section.*

A. *Autumn Term.*

1. Life-history and habits of wasp and humble-bee.
2. Study of a few typical flowers; plan of a flower.
3. Change of flower to fruit. Collection and examination of fruits; classification; methods of seed dispersal.
4. Winter sleep of seeds and other plant forms. The planting of sleeping bulbs. Winter sleep of animals.

B. *Spring Term.*

1. Trees in winter: recognition by (i) branching; (ii) bark, (iii) buds. Examination of buds.
2. Seed-sowing. The forms of familiar seeds. How the farmer and the gardener sow.
3. Seeds grown for study in lamp chimneys, gas jars or test tubes; diagrams of growth. Discovery (i) that water is needed for germination, (ii) that light is needed for healthy growth, and (iii) that seedlings grown apart from soil die when the cotyledons are exhausted.

[7] With the assistance (for the Biological Sections) of Miss C. von Wyss.

4. Subjects to be taken while seed-growing is in progress :—

(*a*) Study of structure of seed and bulb. Were the shoots originally packed within?

(*b*) Comparison of seed with egg; study of hen's egg. Parental care of birds.

(*c*) Frog's eggs; weekly record of changes. Habits of frogs and newts.

C. *Summer Term.*

Studies of plants and animals to be pursued concurrently.

1. Plant Life. Typical spring and summer flowers; need for classification; natural orders; how to use a 'Flora.'

Insect visitors to flowers. Transference of pollen; significance of pollination; fertilisation and cross-fertilisation.

2. Animal life in the pond.

(*a*) Record of growth and metamorphosis of tadpoles.

(*b*) Life-history and habits of : Water-beetle, water-boatman, water-scorpion, caddis-fly, dragon-fly, gnat, water-spider, water-snail.

(*c*) Common pond weeds.

(*d*) Study of green water-plants in aquaria. Evolution of gas noted for future investigation.

Note.—It is desirable that the formal work should be supplemented by (*a*) rambles and excursions to study plants and animals in their natural setting; (*b*) holiday work, including collection of specimens, records of life-phases of some animal or plant, drawings and paintings; (*c*) gardening. Common plots may be worked in school hours for demonstrations and experiments; individual plots in leisure hours.

II. *Physical Section.*

A. *Astronomy.*

Simple observations and graphic records (i) to establish the (apparent) diurnal rotation of sun and stars about an axis directed (nearly) to the Pole Star, and (ii) to explain the principle of civil time-measurement. The observations are to be made, as opportunity offers, partly in and partly out of school hours. The graphic records will be drawn and discussed from time to time in class. The data for the several records may be accumulated concurrently.

1. Direct observation that the sun appears to move. Closer study by means of the shadow of an upright rod gives data for graphic records showing (*a*) the direction of the shadow at a series of fixed times of the day in different months, (*b*) the lengths of the shadow at these times. The latter brings out the facts (i) that the shortest shadow has a fixed direction (south to north), and (ii) that the shadow is shortest (*i.e.*, the sun highest) at varying times shortly before or after 12 o'clock (or 1 P.M. 'summer time ').

Discussion of results (supplemented by the table of 'equation of time' in 'Whitaker's Almanack ') leads to the notions of 'mean noon' and the 'mean solar time' kept by an ordinary clock. The difference between 'local mean time' and 'Greenwich mean time.' Longitude lines as lines of identical local mean time. The international system of standard time-zones, and time-signals by wireless telegraphy. Determination of longitude at sea, &c.

2. Graphic records of the sun's track across the sky on typical days at or near midwinter, the equinoxes, and midsummer. Discussion of these elucidates the varying length of day and night and the correlative phenomena at the antipodes.[8]

[8] The following method works well. A number of thin rods (*e.g.*, long knitting-needles) are mounted perpendicularly at equal intervals along the circumference of a circle marked out on a drawing-board. Each rod carries a small paper or cardboard slider. The board is fixed horizontally in sunshine. As, from time to time during the day, the shadow of one of the rods falls across the centre of the circle the slider is so adjusted that its shadow covers the centre. The heights thus registered are entered upon a sheet of graph-paper whose length is equal to the circumference of the circle, and a

3. Some conspicuous stars and constellations. A circular chart to be drawn showing the Plough, Cassiopeia, Vega, and Capella, with the Pole Star occupying (nearly) the centre. This, pinned to rotate on a cardboard base, serves to record roughly the positions of the stars at different hours of the night and early morning.

Discussion of the records indicates a uniform diurnal rotation of the starry sky about an axis drawn (nearly) to the Pole Star. Specially enterprising pupils determine the approximate inclination of the axis to the horizon.

4. Does the sun appear to move around the same point in the sky as the stars? An affirmative answer obtained by observing the uniform rotation of the shadow of a thin rod. directed towards the stellar pole, upon a cardboard disc fixed at right angles to its length. Use of this (or equivalent) apparatus as a sun-dial.

At the earth's poles the rod (or 'style' of the sun-dial) would be vertical; on the equator it would be horizontal. Parallels of latitude are lines of identical inclination of the style. Elucidation by means of a globe.

5. The following may be commenced in preparation for discussion in Second Year:

(*a*) Record of the noonday (or 'meridian') altitude of the sun measured in degrees by a simple instrument;

(*b*) Record (by means of the rotating star-chart in § 3) of the position of the circumpolar stars at the same hour (*e.g.*, 9 P.M.) on different dates.

B. *General Physics.*

Under this title are grouped simple exercises preparatory to the formal study of hydrostatics mechanics, and the 'properties of matter.' Much of the work should be taken in close association with the course in mathematics.

1. Density and specific gravity. Determination of weights by the balance and of volume by calculation or displacement.

2. The mechanism of the balance and the conditions for true weighing. The laws of the lever. The grocer's scales. Weighing-machines.

The pressure on the fulcrum of a loaded lever. The centre of gravity of a body as a fulcrum, and as the 'centre' of the weights of its parts. Experiments, toys, &c., illustrating stable and unstable equilibrium.

Simple calculations and laboratory experiments on centre of gravity, &c.

3. Time-measurement. (To be taken in connection with A. 4.) Essentials of the mechanism of a simple clock driven by a weight or a spring and controlled by a pendulum. (A single-handed clock, like that of Westminster Abbey, is most suitable.)

Isochronism of the pendulum. Effects of loading or changing length of pendulum. The 'simple' pendulum; connection between swing-period and length. Experimental determination of simple pendulum equivalent to a given pendulum. The balance-wheel in watches and clocks.

Ancient time-measures: the water-clock, the hourglass, &c.

4. Examination of common pieces of mechanism, such as a door-lock, the 'three-speed' gear of a bicycle. (There is scope here for individual work, involving written descriptions aided by diagrams, &c.)

5. The mariner's compass; simple investigation of properties of magnets to elucidate its use. Measurement of deviation of magnet from the south-north line established in A. 1.

C. *Heat.*

1. The varying warmth and coldness of weather as dependent on the season, direction of wind, &c. The thermometer: how it works; expansion of mercury. Necessity of a standard scale of graduation (compare weights and measures). Experimental graduation of a thermometer by placing it in hot and cold water together with a thermometer already graduated.

smooth curve is drawn through the recording points. A well-drawn specimen is pasted on a wooden or cardboard cylinder to be used in the discussion and to serve as a permanent record. The method of 'cylindrical projection' thus taught may usefully be applied in subsequent geography lessons.

2. Expansion as a phenomenon generally accompanying heating. Rough estimates of expansion of water and of metal rods. Expansion and pressure-increase of heated air. Geographical applications.

3. Examination of the steady heating and cooling of water; discovery of constancy of temperature during boiling and freezing.

Definite melting and boiling points of substances. Freezing of sea-water, Melting-points of alloys, &c. Change of volume on solidification: ice, type-metal, dentist's filling, &c.

4. Maximum and minimum thermometers; construction of temperature charts. (Records of wind-directions and rainfall should also be kept throughout the year.)

Second Year.

[Section I. must be taken, as before, in seasonal order. Section II., E., is closely related to it and should be begun in the autumn term.]

I. *Biological Section.*

A. *Autumn Term.*

1. Animal life in the garden. Individual observations, guided by question papers, directions for practical work, reference books, &c., supplemented by class-work. The following are suitable subjects: snail and slug, earthworm, centipede and millipede, earwig, green-fly, lady-bird, hover-fly, lace-wing fly, crane-fly.

2. Soil: general characters of clay, sand, chalk, peat, &c.; closer study of local soil; subsoil. Simple experiments to ascertain proportions of water, clay, sand, silt, grit, and organic matter in a sample of soil.

3. The ingredients of soil. Clay: why called 'heavy'; impervious to water and air; comparison of growth of seeds in pure clay and garden soil; experiments on effects of 'liming.' Experiments to test properties of sand and chalk. Leaf-mould and humus: origin and distribution.

4. Biology of soil. Adaptations of animals that inhabit soil. Why the farmer thinks soil itself 'alive'; demonstration of activity by respiration within the soil. Soil bacteria and protozoa needing air, water, and food.

B. *Spring Term.*

Relation of plant life to soil.

1. Soil-water; comparison of retentive power of different soils. Rise of water in soils; capillarity (see II., C., 3). Importance of hoeing and mulching.

2. Local differences in water-supply of soil; effects on plant forms studied *in situ.*

3. Differences in form of leaves of plants from dry and wet localities. Experimental investigation of differences directed to (i) absorption of water by roots, (ii) loss of water by leaves. Hale's experiments. Construction of potometer. Microscopic examination of leaf-epidermis; stomata, water-pores.

Ascent of water in stem; osmosis (see II., C., 4).

4. Mineral substances in soil as food for plants.

(*a*) Soil-water shown by evaporation (II., E., 1) to contain dissolved mineral matter; comparison with transpired water suggests that the matter is retained by the plant. Suggestion confirmed by examination of ash of burnt plant. The more important constituents. Practical preparation of water and sand cultures. Selective absorption by roots.

(*b*) Rotation of crops. The nodules on roots of leguminous plants; fixation of nitrogen by bacteria. Bottomley's researches. 'Symbiotic' relations between green plants and fungi.

C. *Summer Term.*

Studies in plant physiology.

1. Respiration. Germinating seeds found, like human beings, to emit carbon dioxide. Probability (in spite of negative experimental tests) that the developed plant continues to respire. Reference to behaviour of water-plants

(First Year I., C., 2 (*d*)) leads to discovery that they emit oxygen. Distinction between respiration and assimilation of carbon dioxide. Experimental discovery (i) that both processes occur in plants growing in air, (ii) that oxygen is necessary to plant life, (iii) that breathing proceeds in light and darkness, in cold and warmth.

2. Assimilation of carbon dioxide by plants; importance in general life-economy. Plant substances built up mainly of carbon, hydrogen, oxygen, and nitrogen. The leaf the organ of assimilation of carbon; microscopic differences between leaves according as carbon dioxide is supplied or withheld; starch grains, the iodine test. Starch shown to contain carbon. Manufacture of starch. Relation of starch to other substances in plants. Experiments on relation of light and darkness, cold and warmth, to assimilation; also of seedling leaves, green leaves, and variegated leaves.

3. Assimilation of carbon dioxide as feeding. Comparison of food-processes in plants and animals. Dependence of animal life on activity of the green plant.

II. *Physical Section.*

A. *Astronomy.*

Observations and discussions to lead up to the explanation of the (apparent) annual motion of the sun. The work to be conducted as in the First Year.

1. Revision of, and exercises upon, First Year's work—including the problem of graduating a horizontal sun-dial. (Dials for permanent use may be made in the handwork class, also simple altitude-meters for home observations.)

2. The moon. The class to make a collection of drawings of the phases preparatory to explanation by means of a simple model. The moon observed to move among the stars. Rough measurement of interval between southings. Conception of 'mean lunar day.' (Compare with First Year, II., A., 1. A clock may be regulated to keep 'mean lunar time.') Lunar and calendar months. Note that at the same 'lunar time' on different dates the constellations occupy a series of different positions, repeated each month.

3. Completion of the record begun in First Year, II., A., 5 (*b*). At the same 'solar time' the constellations occupy a series of positions repeated each year. Comparison with results in § 2 brings out that the sun moves among the stars.

4. Continuation of First Year record, II., A., 5 (*a*). Graph of a year's observations to be drawn and compared with similar graphs of former years.

A horizontal line across graph represents the sun's mean altitude at noon and divides the curve into two balancing segments. The sun spends half the year above and half below this line (the 'celestial equator'). The equator corresponds to the plane of the sun-dial used in First Year, II., A., 4. Compilation of a table of the sun's 'declination' from the graph. Use of this table in determining latitude at sea.

Representation of the curve on a cylindrical projection (see footnote to First Year, II., A., 2), the equator being taken as datum-line. The paper above the curve is cut away and the residue bent into a cylinder. The (apparent) annual path of the sun among the stars is then seen to be a plane (the 'ecliptic') inclined at $23\frac{1}{2}°$ to the plane of the equator. Explanation of the seasons.

5. Revision and summary of the two years' work. Distinction between the 'solar,' 'lunar,' and 'sidereal' days. Explanation in terms of (i) a diurnal rotation of the earth about its axis, (ii) an annual revolution of the earth about the sun, (iii) a monthly revolution of the moon about the earth. The Gregorian calendar.

B. *Geology.*

Field-work arranged as part of the course in biology or geography should include observations of the stratigraphical disposition of different types of earth and rock (*e.g.* of the sand and clay on Hampstead Heath in London), and of the relations thereto of the surface features (including the outflow of streams). The nature and effects of river action should also be studied unless taken in a previous year.

C. *General Physics.*

1. How ships float. Measurement of extra displacement produced by adding 'cargo' to a box floating in water suggests Archimedes' Principle. Confirmation in case of other liquids. Extension of principle to bodies that sink. Use of camels and pontoons. Submarine boats. Balloons and airships; contrast with aeroplane.

Exercises on use of Archimedes' Principle in determining volumes and specific gravities.

2. The barometer as a meteorological instrument. Construction of siphon barometer. Pascal's theory of action illustrated by demonstrating increasing pressure at lower depths in a jar of water. The experiment of the Puy de Dôme. Reduction of barometer readings to sea-level for construction of barometric charts. Relation between isobars and winds.

Boyle's experiments in confirmation of Pascal; leading to notion of the 'spring' of the air and to Boyle's Law.

Experiments and apparatus illustrating air-pressure: pumps, vacuum-brake, parcel-transmitter, siphon, &c. The aneroid barometer: its use in determining heights in mountaineering, aeroplaning, &c.

Archimedes' Principle explained by theory of liquid-pressure. The theory applied to explain water-supply systems, hydraulic lifts and engines.

3. Capillarity. Experiments to supplement those of I., C., 1. Measurement of surface tension (in grams-weight per cm.) by rise of water in tube. Simple study of bubbles, drops, and jets; also of common phenomena such as writing with ink.

4. Osmosis. Simple experiments to supplement I., C., 1. Passage of dissolved salts through a porous partition until equality of concentration is set up. Use in purifying beet-molasses. Semi-permeable membranes; law of osmotic pressure; comparison with Boyle's Law for gases. Application to plant-cell.

5. Revision of work of First Year, II., B., 2. Use of spring balance to measure a 'force' (*i.e.* a push or a pull) in terms of weight. Hooke's Law in the stretching of strings, the bending of beams, &c. Use of a single (rough) fixed pulley; measurement of its 'efficiency.' Use of movable pulleys. The Principle of Work introduced for the determination of their efficiency.

Loss of work by friction; simple laws of friction.

Application of Principle of Work to lever, to haulage on an incline (without and with friction), &c.

6. Conditions of equivalence of a single force (*e.g.* a pull in a cord) to two others. The vector law. Applications: the suspension bridge, cantilever frames, &c.

D. *Heat.*

1. Revision of First Year work. Mean temperatures in meteorology; regularity of mean seasonal changes over long periods. Geographical isotherms.

Temperatures at high altitudes and at great depths in sea.

Dependence of boiling and freezing points on pressure; regelation, skating, snowballs.

2. Hot-water circulation; convection. Function of radiators. Loss of temperature through conduction. Experiments on and illustrations of convection, radiation, and conduction: clothing, bark of trees, radiation from gravel and vegetation, &c.; thermostats, the thermos flask, temperature of 'Tube' railways, &c.

Curves of cooling of equal amounts of different substances (*e.g.* water and sand); geographical importance of slow rate of cooling and heating of water.

Lagging of temperature at different depths below surface of soil. (To be taken in connection with I., B.)

3. Extension of First Year, II., C., 3; separation of liquids by distillation. Applications: petroleum industry, turpentine and resin.

Simple treatment of vapour pressure.

Evaporation and condensation. Precipitation of rain and dew. Simple hygrometry; determination of dew-point; relative humidity. Wet and dry bulb thermometer.

Cold produced by evaporation. Ice-making, cold storage.

E. *Chemistry.*

NOTE.—§§ 1-4 should be taken during Autumn Term.

1. Washing soda a *crystalline* substance which degenerates (especially in warm weather) into a shapeless powder. Distillation shows changes to be due to loss of 'water of crystallisation.' Water derivable from other crystals (but not all) and from vegetable and animal substances (*e.g.* a potato) where its presence is not apparent. First notions of chemical combination between substances.

Crystallisation from solution in water. Manufacture of common salt, cane and beet sugar; plaster of Paris; 'sympathetic inks.' Variations in solubility. Crystalloids and colloids. Other solvents (*e.g.* petrol, solvent naphtha in water-proofing, turpentine, &c.) and their uses.

Soluble and insoluble substances in soil. Residue from evaporation of tap-water; formation of sea-water.

2. Use of soda in cookery leads to discovery that it turns the juice of pickling cabbage green. (The juice is extracted by pounding in a mortar.) Vinegar (preferably 'white' vinegar) turns the juice red. Soda and vinegar can 'overcome' one another's effects. Caustic soda, mild and caustic potash, ammonia and lime, being found to turn the juice green, are classed with washing soda as *alkalis*; *acids* are found to turn it red. Other vegetable extracts found to show colour changes with acids and alkalis, *e.g.* litmus. Other 'indicators': phenolphthalein, methyl orange.

Neutralisation; careful study by means of burette, different boys working with different acids and alkalis. Evaporation of neutral solutions reveals presence of common salt when mild or caustic soda is neutralised by hydrochloric acid, and other 'salts' in the other cases. Salts named from acid and alkali (*e.g.* sulphate of ammonia). Manufacture of sulphate of ammonia for manure, and of sal-ammoniac.

3. How does caustic differ from washing soda? On addition of acid the latter yields a heavy gas which extinguishes flames, turns lime-water cloudy and ultimately clears it again. The cloudy matter, when collected, returns the gas if acid is added. Chalk is known to yield the same gas when 'burnt' to make lime. Finally, caustic soda is made by boiling washing soda with lime, the latter becoming converted into chalk. (Similar statements apply to mild and caustic potash.) Thus, washing soda, mild potash, and chalk are to be classed together, and also caustic soda, caustic potash and lime. But there are two 'limes'—quicklime and slaked lime. Dry 'heavy gas' liberates water from caustic soda, caustic potash and slaked lime, but not from quicklime; hence the analogy is with slaked lime.

4. The 'heavy gas' is produced in breathing, and also in the burning of coal-gas, candles, &c. Burning of these substances in a jar demonstrates its production together with water, and shows, further, that one-fifth of the air is consumed. The burning of metals (*e.g.* magnesium), and of phosphorus, sulphur, &c., the rusting of iron, the 'drying' of boiled oil, &c., also remove the 'active' one-fifth of the air and leave four-fifths 'inactive.' Consideration of the mode of manufacture of red lead suggests that if heated it may restore the absorbed active constituent. Oxygen and nitrogen; argon. Manufacture of oxygen from liquid air. Properties and uses of oxygen. Oxides.

The 'heavy gas' is produced without water when pure carbon is burnt in oxygen. It is, therefore, an oxide of carbon. Confirmation by burning magnesium in gas. Oxygen passed over red-hot carbon (as in a domestic fire and in the smelting furnace) produces a gas which burns to form the heavy gas. The latter must, therefore, contain more oxygen (compare litharge and red lead); hence the names carbon monoxide and carbon dioxide.

5. Oxides and oxidation in nature and industry. Oxides of iron, copper, magnesium, aluminium, &c.; ochres and other painter's colours; 'drying' of oils; linoleum.

6. Is water also an oxide? Affirmative answer obtained by passing steam over hot magnesium. Discovery of hydrogen. Production in bulk by passing steam over hot iron; properties. Known to be produced also when the plumber 'kills spirits of salt' with zinc. Composition of water confirmed by burning a

jet of hydrogen obtained by this method, and by using the gas to 'reduce' oxides; also by electrolysis. Reducing action of coal-gas.

Carbon and hydrogen constituents of living matter; also nitrogen, sulphur, and phosphorus.

Solutions of the oxides of carbon, sulphur, and phosphorus are acids. Carbonates, sulphites, sulphates, phosphates.

7. Action of sodium, potassium, calcium (all obtained by electrolysis) on water. Deductions: quicklime is an oxide; slaked lime, caustic potash and caustic soda are hydroxides; chalk, mild potash, and soda are carbonates. Action of heat on carbonates: iron carbonate (spathic ore), zinc carbonate (calamine), magnesium carbonate (magnesian limestone); manufacture of white lead.

8. Examination of action of dilute hydrochloric and sulphuric acids on zinc, iron, magnesium. Salts of these metals. Salts also produced (without hydrogen) by action of acids on oxides. Theory of action confirmed by passing dry hydrochloric acid over heated oxides. Salts named from acid and metal (*e.g.* sodium chloride). The special case of 'ammonium' salts.

9. Manufacture of sulphuric acid by 'contact process.' Manufacture of hydrochloric, nitric, and phosphoric acids from salt, saltpetre, and calcium phosphate. Sources of these salts. Salts in the soil (see I., B., 4).

10. Summary of results in (verbal) chemical equations. The quantitative constancy of chemical reactions and combinations (discovered in numerous simple gravimetric and volumetric exercises during the course) is also to be brought out and emphasised.

Third Year.

[Section I. is assigned to the second and third terms. The divisions of Section II. may be taken in any convenient order.]

I. *Biological Section.*

A. *Spring Term.* A study of micro-organisms.

1. Action of yeast in bread-making as an example of *fermentation.* Cultivation of yeast in Pasteur's solution. Fermentation in manufacture of beer and wine; acetic-acid fermentation. Pasteur's proof that different effects are due to activity of definite plant-growths. Association of fungi with other changes in food materials: moulds on bread, jam, &c.; fungi in milk; colonies of bacteria in putrefying broth, meat-jelly, &c. Germ-cultures; practice and theory of staining.

2. The source of fermentation-fungi. The 'spontaneous generation' controversy; Appert's invention (*c.* 1800) for fruit preservation; experiments of Schultze and Swan, sterilised air; germs and dust, the Pasteur flask.

Presence of germs in tapwater, dust, and surface soil demonstrated by cultivation in Lister's tubes.

Sterilisation by heat; resisting germs (*e.g.* in dirty milk).

Sterilisation of food by preservatives—harmless and harmful.

3. Micro-organisms in disease. Pasteur and silk-worm disease; Lister and the antiseptic treatment of wounds; Manson and Ross and malaria. Phagocytes and bacteria; recent developments of antiseptic practice. Vaccines and anti-toxins: Jenner and vaccination; Koch and Pasteur and anthrax, rabies; Wright and typhoid fever. Anti-toxins in diphtheria, tetanus, &c.

The extermination of infectious diseases: rabies in England, malaria in Panama, &c. Preventable diseases still to be exterminated; need of scientific investigation, educational enlightenment, and administrative action.

4. Micro-organisms as useful agents: cheese-making, tanning, &c.; micro-organisms as scavengers; the fixation of nitrogen.

B. *Summer Term.*

1. The structure and life-history of select animal types: Euglena, Paramœcium, Vorticella, Hydra, sea-anemone, earthworm, crayfish, frog, rat, or rabbit.

2. Structure and life-history of Spirogyra, a moss, a fern.

II. *Physical Section.*

A. *Astronomy.*

The following subjects should be taken in class. Further voluntary work may be directed and encouraged by the School Science Club.

1. Revision of previous work. The fundamental importance of sidereal time. The astronomical clock. Fixing positions of stars by right ascension and declination. Construction of star-charts. (In connection with these the use of the polar and meridional gnomonic projections may be either taught or applied from the geography course.)

2. Plotting of monthly course of the moon upon a cylindrical projection (compare Second Year, II., A., 4), right ascensions and declinations being taken from 'Whitaker's Almanack.' The path of the moon thus shown to be approximately a plane inclined to the ecliptic.

Plotting on enlarged scale of paths of moon and sun about the times of new and full moon. (It is best to use the gnomonic projection, since the paths are then straight lines.) Conditions for eclipses.

3. The variation in distances of sun and moon deduced from varying observed diameter. (Data from 'Whitaker's Almanack.') Perihelion and aphelion; perigee and apogee. The orbits of earth and moon elliptical. Calculation of eccentricities.

Regression of moon's node; influence on dates of eclipses. The precession of the equinoxes.

Simple theory of tides.

4. The planets. The Ptolemaic and Copernican theories.

The relative distances of the planets from the sun and of the moon from the earth. Measurements of absolute distances by parallax, transit of Venus, &c. Kepler's laws.

B. *Geology.*

The following subjects may be expected to be taken during this year in geography lessons :—

1. The stratigraphy of the home region. One or two lessons based on evidence acquired on field-excursions or reported by individual pupils, museum collections, &c. Thus, in London a clear idea should be given of the geology of the Thames basin from the northern to the southern chalk heights, the evidence of borings for artesian wells, &c., being examined. The probable geological history of the region.

2. Extension to neighbouring regions : for example, in London to the Weald, Surrey, Hants, and the Isle of Wight.

3. Outline of the geological structure of typical regions, such as Wales and the northern coal-fields of England.

C. *Mechanics.*

The following subjects are to be regarded as territory common to the courses in science and mathematics. Much (or all) of the work may be taken in mathematics lessons.

1. Uniform and variable velocity (linear and angular), average velocity, velocity at a given moment; distance-time and speed-time graphs.

Two cases of special importance : (i) Falling bodies and projectiles. The vertical distance fallen found to vary with the square of the time; hence the average, and therefore the final, vertical velocity must be proportional to the time. Value of 'g.' (ii) Pendulum motion. Here, since the time of swing is constant for small arcs the average velocity is proportional to the amplitude. It follows that the velocities at all corresponding moments, including the moment of mean position, are proportional to the amplitude.

2. Velocity as a vector. Relative velocity. Vectorial representation of changes of velocity. Utilisation of the property given in 1 (ii) to measure changes of velocity produced by collision of swinging balls (Goodwill's 'Vector Balance').

Discussion of results leads to distinction between weight and mass, to the idea of change of momentum as the measure of the dynamical action of bodies upon one another, and to the principle of conservation of momentum. Alternative measure of force (hitherto measured in terms of weight) as rate of change of momentum. The poundal and dyne.

Weight as rate of change of momentum. Newton's Law of Gravitation. His verification by calculation of rate of fall of moon.

3. A suspended ball is made to swing through a constant vertical distance along various curves, and to collide directly with a stationary suspended ball. Measurements show that the velocity immediately before impact depends entirely on vertical distance fallen. Connection of result with Principle of Work (Second Year, II., C., 5). Kinetic energy. Apparent loss of energy in collisions (considered in connection with D., 4).

D. *Physics.*

1. Revision and extension of Second Year work on radiation and conduction. Graphic study of temperatures at points on a bar heated (i) steadily (Forbes), (ii) rhythmically (Ångstrom), to illustrate measurement of conductivity and seasonal temperature-changes of soil.

2. Solar radiation : its fundamental importance. Separation by prism into light and dark radiation. Intensity of radiation : law of inverse squares; photometry; the cosine-law; Newton's law of cooling. Influence of character of radiating and absorbing material; the incandescent gas-mantle, &c. Absorption and reflection of light and dark radiation. Laws of reflection : plane and curved mirrors. Applications : periscope, searchlights, lighthouses, &c. The sine-law of refraction; indices of refraction.

3. Heat as a measurable quantity. Study of the temperature-changes of variable weights of water heated for the same period by a constant flame leads to the formula $H = Wt$, where W is the weight of water, t the rise of temperature, and H the number of 'calories' represented by the heating. Repetition with other liquids (*e.g.* linseed oil, glycerine) leads to the more general formula $H = sWt$, where s is a constant for each substance (the 'specific heat'). Confirmation by 'the method of mixtures.' Measurements of specific heat.

Latent heat. Rough determination of latent heat of steam by Black's method, of water by method of mixtures.

4. Temperature-changes of gases under the conditions (i) of constant pressure and (ii) of constant volume. Absolute temperature.

Cooling and heating of gases by adiabatic expansion and compression. Applications of results in meteorology. Equivalence of the heat-change to work done. Joule's experiments, &c. Internal-combustion engines. Liquefaction of gases; cold storage, &c.

5. Vapour pressure. Variations of boiling-point with pressure. Steam-engines (cylinder and turbine). Uses of superheated steam (in engines, in chemical industries, &c.), and of subheated steam (concentration of beet sugar).

6. Electricity : a preliminary course of work, almost entirely qualitative in character; the quantitative aspect of the subject being reserved for study in the Fourth Year. Examination of an electric-bell circuit as a type of electro-magnetic mechanism. Analysis of magnetic effects of the current : Oersted's experiment, Maxwell's screw rule. Industrial and other uses of electro-magnets. The electric telegraph. Magnetic effect as an index of current strength; the galvanometer. Preliminary notions of voltage and resistance.

The electric bell as a motor; elaboration of the same principles in the motors used for locomotion and power.

Faraday's experiments on electro-magnetic induction. The induction coil. The dynamo; the 'magneto'; reciprocal relation between the principles of the motor and dynamo; conversion of mechanical into electrical energy, and of electrical into mechanical. The telephone.

Conversion of electrical energy into heat; the incandescent and arc lamps; the electric furnace.

Electrolysis : industrial applications. Secondary batteries : relation with primary batteries with reference to conversion of chemical into electrical energy and electrical into chemical.

E. *Chemistry.*

1. Revision and extension of Second Year work.

(*a*) The aim of chemistry to regard all substances as elements or compounds of elements. Quantitative definiteness the mark of chemical union. Distinction between compounds, mixtures, and solutions.

Alloys and glass as 'solid solutions': conversion of iron into steel; manganese steel; manufacture of glass. Amalgams of mercury; the extraction of gold.

(*b*) Law of multiple proportions, based on analysis of sodium bicarbonate, lead peroxide, &c. Provisional use of the terms 'molecule' and 'atom' to describe results. Molecular composition of water. The basicity of acids. Use of chemical formulæ and equations. Valency of the common metals.

(*c*) Combustion. Nature of flames. The incandescent gas-mantle. Use of high-temperature flames in welding, cutting steel, &c. Flameless combustion.

(*d*) Sulphides, sulphuretted hydrogen: their analogy with oxides and water. Action when sulphides are roasted; applications in metallurgy.

(*e*) Acidic and basic oxides, peroxides. Action of sulphuric acid on peroxides; hydrogen peroxide. Dry hydrochloric acid passed over a heated peroxide (*e.g.* red lead) yields chlorine. Its properties. Molecular constitution of hydrochloric acid. Bromine and iodine. Oxidation and reduction as general chemical processes.

(*f*) Ammonia: its composition. Ammonium salts.

2. The law of chemical equivalence. Determination of weights of metals that (i) displace equal volumes of hydrogen, (ii) unite with equal weights of oxygen, (iii) replace one another in salts. Confirmation of results by determining the volume of hydrogen and the weight of oxygen involved in the decomposition of steam by hot iron. Equivalent weights. Smallest combining (or 'atomic') weights, that of hydrogen being taken as unity.

3. Revision and further applications of previous work in simple explanation of some important chemical industries and processes. (*a*) The winning of the more important metals. (*b*) Coal-distillation; the main products and their uses. (*c*) Soda; bleaching powder. Bleaching. (*d*) Tanning. (*e*) Dyeing. (*f*) Phosphorus: matches. (*g*) Photography. (*h*) Glass and pottery.

Fourth Year.

[In schools where the arrangement is possible the subjects marked with an asterisk should be reserved for a course of lectures and discussions to be given (to non-specialists in science together with specialists) in the fifth year. This course should include some treatment of the philosophy of science illustrated from the history of scientific discovery. Classical works in biology or physical science may be recommended for private reading and discussion.]

I. *Biological Section.*

1. Civilisation based on the domestication of plants and animals. The history of food-plants, &c. Modern methods of improving breeds of plants and animals. Vegetable and animal products in industries and manufactures: cotton, timber, paper manufacture, wool, silk, &c. Importance of forestry.

* 2. The theory of organic evolution. The evidences and main phases of the evolutionary process: the beginnings of life; divergence of animals and plants from one another; main morphological developments along each line; origin of sex; general character of progress—'progressive differentiation and integration'; adaptation to environment, degeneration.

Problems of heredity and variation: Darwin, Mendel, de Vries. Selection. Function and environment.

II. *Physical Section.*

A. *Geology.*

Lessons should be given (in, or in close connection with, the geography course) on (i) the forms of life characteristic of the chief geological horizons,

including the earliest appearances of man (*cf.* I., 2); (ii) special subjects of geographical importance, *e.g.* the coal age and the ice age, 'block' and 'fold' mountains, rifts and faults; (iii) questions of economic geology selected on the ground of either local or national importance. In connection with (i) visits should be made to a geological museum, and holiday collections of fossils encouraged by the School Science Club.

B. *Mechanics.*

1. Revision of work of Second and Third Years; straightforward problems on motion and equilibrium to give a firm grasp of principles.

Rate of doing work; horse-power; dynamometers. Work of engines in road, rail, and water traffic. Economy of power.

Simple theory of the aeroplane.

2. Circular motion. Harmonic motion of pendulum, vibrating spring, &c. Connection with Hooke's Law (Second Year, II., C., 5).

The formulæ $y=a \sin \frac{2\pi}{\lambda}(x \pm vt)$ as descriptive of progressive harmonic waves. Stationary waves. Wave-motion as a mode of transmission of energy.

3. The principle of energy in the case of a thin cylinder rotating about its axis while the latter is moving parallel to itself. Determination of 'g' by measuring time taken by such a cylinder to roll down a sloping plane.

Derivation of the principle of Conservation of Moment of Momentum, and of the formula *torque=rate of change of moment of momentum.* Applications to phenomena of bicycling, spinning tops, gyroscopes, &c. Moment of inertia and radius of gyration in simple cases. Motion of a rod struck at a given point. Harmonic vibration of a compound pendulum and of a horizontally suspended magnet. Inversion of compound pendulum; 'centre of percussion.'

C. *Physics.*

1. Electro-magnetic measurements:

(*a*) Distribution of magnetism along a bar-magnet. Magnetic fields; lines of force; use of small compass-needle to map field near magnet or current circuit.

Deflection of small compass-needle by magnet; the tangent law; application in the tangent galvanometer. The moment of a magnet.

(*b*) Chemical equivalence of substances liberated by a current passing through electrolytic cells in series. Definition of the ampère in terms of silver deposited per second. Congruence with measurement in terms of deflection in tangent galvanometer.

(*c*) A long platinoid wire is 'tapped' by the terminals of a high-resistance galvanometer. The results lead to the notions of a regular 'fall of potential' and of the connection of potential difference with current-strength and resistance. Definition of the ohm and the volt. Ohm's law.

(*d*) Quantitative statement of Faraday's law of induction. The earth-inductor; the transformer. Magnetic force and magnetic induction in iron; permeability; hysteresis.

2. Optical measurements and calculations.

(*a*) Spherical mirrors; theoretical derivation of the formula $1/v+1/u=1/f$; experimental verification.

(*b*) Lenses: experimental discovery of the formula $UV=f^2$; deduction from this of the formula $1/v-1/u=1/f$. Magnification; telescopes, microscopes; the prismatic field-glass. Achromatic lenses. The lens of the eye and its optical defects; spectacles.

(*c*) Methods of determining the velocity of light.

3. Wave-motion in sound, light, and electricity.

(*a*) General properties of harmonic wave-motion, longitudinal and transverse (to be taken in connection with B., 2). Application to elucidate the behaviour of sounding forks, strings, and pipes. Free and forced vibrations; resonance.

(*b*) The undulatory theory of light. Colours of thin films, interference; diffraction; polarisation. Deduction of behaviour of mirrors, prisms, and lenses

from wave-theory. Spectrum analysis: applications in chemistry, astronomy, &c.

(c) Electro-magnetic waves. Wireless telegraphy. Electro-magnetic theory of light.

* 4. The main results of modern investigations on the discharge of electricity through gases; Röntgen rays; radioactivity. The ultimate constitution of matter: the kinetic theory of gases, the radiometer; experiments of Perrin and Bragg; theories of solution, osmosis, and electrolysis.

* 5. A general review of physical (including chemical) phenomena from the standpoint of the principle of the Conservation of Energy. Availability and degradation of energy. The world's present and possible future sources of energy. Economy of energy.

D. *Chemistry.*

1. The atomic theory; Avogadro's hypothesis. The density of a gas and its volumetric reactions as an index of its molecular constitution. Relations between oxygen and ozone, acetylene and benzene.

2. Composition of ordinary alcohol. It behaves like a weak hydroxide, yielding 'ethereal salts' and a substance, ether, which is analogous to an oxide. Ethane and its relations to alcohol. Comparison of ethane with methane ('natural gas'), alcohol with wood-spirit. The paraffins, their alcohols, ethers, &c., as homologous series. Theory of the carbon atom. Formic and acetic acid: their relations to and reactions with alcohols. Chloroform and iodoform.

3. The manufacture of soap, candles, and glycerine. Fats and vegetable oils are ethereal salts, glycerine and alcohol; hydrolysis. Nitro-glycerine and dynamite.

Cellulose, collodion, gun-cotton, blasting, gelatine, cordite.

4. Benzene and toluene as 'closed chain' compounds. Isomerism. Carbolic acid; salicyclic acid, 'aspirin'; tannin, nitro-benzene, aniline and the aniline dyes. 'T.N.T.' explosive. Picric acid.

5. The proximate constituents of food: proteins, carbo-hydrates, fats. Separation of the protein (gluten) and the carbo-hydrate (starch) in flour; of the protein (curd), carbo-hydrate (whey), and the fat (cream) in milk. Tests. The conversion of starch into soluble sugar, solution of meat-stuffs; enzymes, their rôle in plant life and animal digestion. Food values. Ultimate constituents of foods and of living matter. Anabolism and katabolism.

* 6. General review.

(a) Chemical industries from the standpoint of the nation and the world. By-products, economy. Interrelations of theory and practice; synthetic chemistry, the microscope in metallurgy, &c.

(b) Inorganic and organic chemistry. Families of elements and compounds. The periodic table of the elements. The new elements.

IV. Science Scheme of a Rural Secondary School.

By William Aldridge, formerly Headmaster, Shepton Mallet Grammar School.

The school in which the work here described is carried on is an old endowed Grammar School, founded in 1627, which was reconstituted and transferred to new buildings nearly twenty years ago. The commencement of the experiment in rural education in this school was coeval with this change, and the work has been continued ever since. For the first few years aid was given by the County Council alone, but grants were afterwards obtained from the Science and Art Department, and ultimately the school came under the Board of Education, which, however, refused to give a special grant under Article 39 of the Regulations for Secondary Schools, on the ground that the work was no longer an educational experiment but was a proved success.

The scheme has undergone modifications since its inception, but the position reached is roughly outlined below, and there is no doubt as to its efficiency as a means of general education.

The underlying motive of the scheme is to vivify the class-room teaching by bringing it into intimate contact with the out-of-school life of the district in which the pupils move, thereby making the pupil an interested learner, developing into an accurate, observant, reasoning, and adaptable man, with bodily, mental, and spiritual faculties developed to the fullest possible extent.

The school is situated in a small market-town of 5,000 inhabitants, served by two lines of railway. The number of pupils has varied from fourteen at the start to eighty-five, and now averages about seventy to seventy-five boys, aged eight to eighteen, of whom all, except at most half-a-dozen, are day boys. About two-thirds of the total come from surrounding towns and villages. The chief industries of the locality comprise farming (milk, cheese, butter, and cider making, with little arable land), brewing, quarrying, coal-mining, a little lime-burning, brick-making, and the manufacture of lace-making machinery. The school staff consists of the headmaster and four assistants, who receive occasional help in the more technical portions of the science course from the county experts in agriculture and horticulture.

The buildings comprise a main block, including headmaster's house and three class-rooms, cloak-room, &c., and a detached block containing workshop, physical and chemical laboratories, lecture-room, balance-room, and store-rooms. The physical laboratory is also used for practical botany, but experiments in this connection are also set up in the lecture-rooms and chemical laboratory.

Out-of-doors about two-fifths of an acre are devoted to experimental and demonstration plots, and there is a meteorological station. Formerly the plots included gardens cultivated by individual boys, but they proved to be unsatisfactory and of little real educational value, and were ultimately abandoned. A model fruit plantation has been substituted. The boys are not called upon to do much manual labour in connection with these plots, but they use them largely for experimental and observational work.

For science work the school may be divided into three main divisions—Preparatory, Middle, and Upper—and a boy spends an average of three years in the Middle Division after reaching the age of twelve years. The following is the division of time in class which has been found to give satisfactory results :—

Preparatory Division, 8-12 *years old.*—Religious knowledge, 1½ hour per week; English subjects, including reading, writing, spelling, grammar, composition, history, geography, 15 hours; arithmetic, 7½ hours; physical exercises (excluding organised games), ¾ hour; art and music (singing), 2¼ hours; science, 1½ hour.

Middle Division, 12-15 *years.*—Literary subjects, including religious knowledge, English, geography, history, 7½ hours; mathematics, 6 hours; language (French), 3¾ hours; manual and physical training (apart from organised games), 3 hours; science, 6 hours; art and music 2¼ hours.

Upper Division, 15-18 *years.*—Literary subjects, 9 hours; mathematics, 6 hours; language, 5¼ hours; science, 6 hours; physical training, ¾ hour; art, 1½ hour.

In the Preparatory Division the science taken is of an informal character, such as that usually included under the term 'Nature Study.' The object of the course is to stir up interest in Nature at large, and to develop the observational and descriptive powers. Plants, animals, insects, natural phenomena, simple experiments in mechanics, chemistry, physics, &c., are all drawn upon to furnish subject-matter. Scientific terms are, as a rule, avoided, but accuracy of observation and of description are demanded. The lessons usually take the form of a conversation between the teacher and the class on the specimens to be described, or the experiment to be observed. It is a general rule all through the school that every observation made or answer given shall be a complete sentence grammatically constructed, and 'No' or 'Yes' without amplification is never accepted as a satisfactory reply. Sketches are frequently made in the course of the lesson, and the information gained is often utilised in the next lesson on English composition or a question upon it is set to be answered as home-work. The boys frequently suggest subjects for future

lessons, and the indoor lessons sometimes develop into country rambles and scientific excursions with a definite object in view on half-holidays. Outdoor lessons in class hours are not usual. They have been found unsatisfactory, as there are too many distractions and much valuable time is lost.

In the Middle Division science becomes more systematic; the system is not, however, that of the text-book, but is determined by the underlying principle that the elements of botany, physics, chemistry, &c., shall be made to throw as much light on country life as possible. The various subjects are therefore blended more or less into a whole and not kept in watertight compartments. For convenience, chemistry, physics, and botany are treated separately in different lessons, but one period per week is devoted to what is called 'Rural Economy'—an application of scientific knowledge to the elucidation of the mysteries of rural life.

The outlines of the chemistry course at this stage are published and need not be repeated here. (See 'A First Course in Practical Chemistry for Rural Secondary Schools,' published by G. Bell & Sons, 1*s.* 6*d.*)

The physics course begins with a general lesson or two on matter and its properties, and proceeds with heat—expansion, liquefaction, vaporisation, conduction, radiation, absorption—temperature and its measurement; heat as a form of energy—its production by chemical and physical means—its measurement—specific heat—latent heat; anomalous behaviour of water with respect to heat and its importance in the economy of nature—vapour pressure—boiling; atmospheric moisture—its measurement—effect on barometric height—the connection of the barometer with weather phenomena, &c.

General Physics and Mechanics.—Methods of measurement—mass—density—flotation—osmosis—surface tension—capillarity—fluid pressures—siphon—pumps—hydraulic press—barometer—Boyle's and Charles' Laws—levers—pulleys—work—time and its measurements—friction (how minimised in machinery)—inclined plane—parallelogram and triangle of forces—motion—velocity—acceleration—momentum, &c.

Botany.—The structure of a plant so far as observable with a pocket lens. Seeds and seedlings—roots, their structure and work—stems, branching, buds, effects of pruning—the green leaf and its work—flowers. essential and non-essential parts, their use and importance—fruits, how formed, uses, dispersal, life-histories of common plants and weeds. How plants feed—comparison of plants, leading to a system of natural classification—contents of plant cells—enzymes and their work—the nutrition of plants and animals compared—reproduction processes, &c.

Rural Economy.—Soil, its origin, composition—agents of denudation—work of lowly animal and plant life in formation of soil—characteristics of sand, clay, silt, lime, humus—heavy and light soils—soil and subsoil—why differences—food materials of plants, how and whence obtained—fertility, how maintained—tillage—reasons for operations—effects on soil moisture, soil air, soil temperature, plant food, &c.—chemical knowledge applied to manuring and its principles—farmyard dung—chemical fertilisers, their composition, production, and mode of action—application of scientific principles to farm operations, *e.g.* haymaking, grazing, ensilage—bacteria, yeasts, moulds and their work—nitrification and densification—souring of milk—putrefaction—decay—ripening of cheese—souring of cider—sterilisation—pasteurisation—preservatives—plant diseases and pests—remedies and preventives, &c.

The above is not an exhaustive syllabus, but it gives an idea of subjects treated, though not of the order in which they are taken up. The lessons consist of conversations and discussions carried on in connection with specimens, experiments, demonstrations, diagrams, and so forth. The whole is treated in an experimental and descriptive manner, and the connection with local industries and phenomena is constantly kept in view. Laboratory work goes on in connection with the course, but, except in chemistry and botany, no attempt is made to keep lecture discussions and practical work together. In the physical laboratory the course commences with practical mathematical measurements and verification of mensuration formulæ, and then proceeds to determinations of

volumes, densities, &c., flotation, hydrometers and their uses—mechanics and simple machines—capillarity, surface tension, friction, gravitational and other forces, and so on, always keeping the fundamental object of the course in view and choosing objects and illustrations in accordance therewith. The object of each experiment is stated, results obtained, and finally a full description of the method followed is written out in pencil at the bench, deductions and inferences are drawn, sources of error are sought for, and their effects estimated. As a rule each boy, or pair of boys, has a separate problem from his fellows.

As a sample outline of a lesson in 'Rural Economy'—suppose the subject is *Rolling*, which the boys have seen proceeding in the meadows early in March as they came to school. The investigation probably brings out the following points:—Smooth surface—hoof-marks of animals—presses in stones (how came they to surface? lifted by frost—laid bare by washing of rain, &c.), hence minimises risk to mowing machine later on—makes surface firm—loosened by winter frost; effect on capillarity—capillary tubes made finer, therefore water rises to top; effect on evaporation—air usually moist at this season, therefore slight; effect on soil temperature—evaporation causes cooling tendency—tight soil a better conductor than loose soil—sun beginning to have more power—tends to make soil warmer—total of effects, warming; effect on plants—warmth causes more rapid growth—roots in loosened soil would tend to be short of food and to be dried up and withered—seedling grasses pressed into soil and enabled to grow—shoots broken—causes dormant buds to grow out—result, a thicker and more abundant crop of grass. Effect on conservation of soluble plant food formed during winter—capillarity keeps it near roots. Why do we now start rolling the cricket pitch?

The whole of the information can be elicited from the class by serial questions.

Up to this point few text-books have been used, but note-books contain summaries of all lessons and home-work exercises on them. In the course of the lessons interesting facts about the history of science and its pioneers are given as occasion arises.

In the higher division text-books are used more freely and the different branches of science are followed out still more systematically; but the underlying principle of the course is never forgotten, and applications of the facts are constantly demanded. Heat, light, and sound, studied as forms of energy, and magnetism and electricity are taken in alternate years. Chemistry is further developed, and botany is revised and extended to include plant ecology and the study of some of the commoner orders. Soil physics and soil biology are further developed, and the chemistry is applied to crops, animals and animal products, feeding stuffs, manures, &c. Enough animal physiology is given to enable boys to understand the digestive and feeding processes in animals, and to compare these processes with those in plants, bringing out the fundamental difference that plants in total store up energy, and animals in the total liberate and use that energy in various ways. An outline of the chemistry of foods and the principles upon which animals are fed is dealt with (the boy's own body being *the* specimen usually under immediate consideration). The reproductive process is traced through plants, and the principles of breeding can thus be dealt with in systematic order, while many valuable lessons can be impressed without difficulty.

The laboratory work takes on a character more closely resembling research work, and sometimes deals with problems connected with soils, plants, feeding materials, manures, milk and milk-products, &c., requiring the application of knowledge and methods previously studied in some other connection. The lines along which such studies are to be conducted are usually suggested by the master, but may be modified by the pupil at his discretion.

In the physical laboratory the exercises are connected with the branch of science under study, and the compound microscope is now used in the study of botany.

Meteorological instruments, soil temperatures, &c., are read and recorded daily, with occasional discussion of the meaning and explanation of the records.

The school has a Natural History Club. Excursions are frequent. Regular

meetings are held at which boys read papers which usually embody their own observations and are illustrated in their own ways. These meetings and excursions take place out of school hours.

V. Science Course for a Public Secondary School for Girls.

By I. M. Drummond, Headmistress, formerly Science Mistress, North London Collegiate School; and R. Stern, Science Mistress, North London Collegiate School.

(Average time given about three hours per week from twelve years of age.)

I. *Ages up to* 11 *or* 12.—The power of clear, logical reasoning makes rapid strides about the age of twelve, and this, therefore, would seem the most suitable age at which to begin a definite course of experimental science. This by no means precludes the study of natural phenomena before this stage. Indeed, such study must begin as soon as a child wakens to interest in the world around her. Science for these younger children will take the form of observations on, and very simple experiments with, growing plants, caring for animals, and watching them; recording observations on sun, sky, and weather; investigating the structure of simple machines in daily use, and finding out how they work. The material should be as varied as possible, and should follow, as far as this can be done, the interest of the children at the moment, the continuity of work throughout a course of lessons being, as a rule, a minor consideration.

II. *Ages* 12 *and* 13.—When regular work in the laboratory first begins at about the age of twelve the lessons must necessarily become more systematic. The main objects of the teacher at this stage will be :—

(*a*) To encourage the natural inventiveness of the child and to help her to direct it towards definite ends.

(*b*) To encourage her to give practical expression to her ideas by her own manipulative skill.

(*c*) To help her to distinguish between observed facts and the inferences to be drawn from them, and to express herself accurately in written records.

The problems must be closely connected with the everyday life of the child, and at first should be so simple that an experiment. complete in itself as far as it goes, can be carried out in a single lesson. The power to follow a line of argument, and to draw inferences by collating the results of several experiments, comes at a later stage. Easy problems relating to simple mechanical appliances, flotation, pressure of liquids and gases, effect of heat on substances, its method of transmission and its measurement, all form excellent material. The method of attack and the actual choice of problems may vary widely. Some teachers may begin with the investigation of an actual instrument; others prefer to begin with a discussion of the phenomenon of weight, leading the children to realise at the outset how little they know as to what weight really is, but that they have some knowledge to start with in their experience that one body is harder to lift than another, and that one presses more heavily on the hand than another. The idea of a downward force is thus obtained, and methods of measuring it may be discussed. The impossibility of making accurate comparisons by means of feeling the weights leads to the devising of a simple instrument. The pull on a bit of elastic may be measured, and a realisation of the imperfections of this instrument, owing to incomplete elasticity, will lead up to the spring balance. Other methods of comparing weights lead up to the see-saw, and so on to the structure of the kitchen scales and the laboratory balance. The value of a piece of fine and delicate machinery is thus appreciated and it is treated with respect. A comparison of the weights of different objects leads rapidly to the need for a standard or unit of weight.

Experiments with the see-saw show the result of altering the position of the fulcrum, and this leads on to levers and experiments on mechanical advantage. Pulleys and inclined planes will now naturally be experimented with. Observations will be made on the working of pickaxes, cranes, wheel and axle, and so forth. Models may be made by the children, and many problems may be

answered by their own experiments, as, for example, if a loaded wheelbarrow has to be raised to a certain height, is it better to have a short steep slope or a longer and more gradual one ?

A study of flotation may very naturally develop from such a course as this. Why do some bodies float on water and others sink ? Why do some bodies float higher in the water than others ? Why do bodies float higher in salt than in fresh water ? Is any of the weight of a body that sinks supported by the water ? These will be among the questions asked and answered by experiments. They will lead up to an understanding of relative density, and of the Principle of Archimedes. When the principle has been grasped, practical applications should be worked out, calculations being made and the results tested by experience. The weight of cargo which it is safe for a boat to carry, or the size of a cork life-belt necessary to support a person, are problems which, even if toy boats and tin soldiers are used, help the children both to grasp the practical value of the knowledge gained and also to appreciate the need for accuracy.

The fact that ice floats on water may well lead on here to investigations into (1) changes of density and volume produced in substances by change of temperature, (2) change of state, together with the influence of pressure upon it, (3) some methods of transmission of heat, and (4) means of measuring temperature and heat. Plotting curves of temperature for the heating of water over a flame till it boils, and for the cooling of melted paraffin wax, will give the idea of latent heat. The heating of a definite weight of water by the immersion in it of given weights of different substances at the same temperature will give the idea of specific heat, and these conceptions may now be developed in their geographical and practical bearings. Discussions as to the methods of heating buildings and obtaining hot-water supply, the working of a cooking-box, &c., will naturally arise during this course.

Flotation in the air will lead on to an estimate of the weight of air by the method of driving it from a flask by boiling water, and this to the idea of pressure of the air. The experiments of Torricelli and the work of Boyle on the 'Spring of the Air' may here be considered in historical order, and different forms of barometer, pumps, siphons, and so forth may be studied. A consideration of winds and of weather charts will here, again, form a link with geography.

At this stage a continuous piece of investigation necessitating the framing of tentative inferences or hypotheses, and the testing of these by further experiment, becomes increasingly possible, and helps greatly to deepen the understanding of the method of development of scientific knowledge. Many chemical problems form excellent material. Amongst others, the problem as to what we understand by burning arises very naturally out of work already done.

Preliminary questioning as to what burning is will usually lead to the suggestion that it consists in a partial or complete disappearance or 'consuming' of the object burned. Experiments with match, candle, &c., *seem* to confirm this ; the weighing of magnesium before and after burning discredits it, and demands, therefore, further investigation. The fact that some member of the class has probably observed the magnesium glow more brightly on the lid of the crucible being removed, suggests that air influences burning and may cause the increase of weight. The question then arises, does the air then diminish ? Burning magnesium in a crucible floating on water under a bell-glass shows that it does. Therefore the magnesium calx must represent magnesium and air. Why has the whole air not disappeared ? Suggestions that this may be due to insufficient magnesium being burned must be put to the test, and the properties of the gas left compared with the properties of the air to begin with. Details of Priestley's and Lavoisier's experiments with the red calx of mercury may now be given for comparison, and the red calx heated by the pupils. Other substances may then be dealt with, *e.g.*, carbon. Carbon disappears. Is a new gas formed ? Collection of the air above the heated carbon and testing of this, together with ordinary air, by a match, by litmus, and by lime-water, reveal the fact that a new gas has appeared. Probably someone, in the effort to collect the gas, has failed to get the carbon to disappear, owing to heating it in too limited a supply of air ; this will lead to the suggestion that the carbon also unites with oxygen. Heating small quantities in oxygen and nitrogen will reveal the fact that no new gas is formed in the latter case, while it is formed abundantly in the former. A further confirmatory experiment may be made by the burning of magnesium in carbon dioxide.

The candle can now be more thoroughly investigated, the decrease in volume of air demonstrated by burning it over water under a bell-jar, and the products of combustion found. This will naturally lead to the question—Is water an oxide? and its composition may be proved by the burning of magnesium powder in steam, with the formation of magnesium oxide and a new gas, hydrogen.

A closely knit piece of work of this kind, in which fresh materials and facts are arbitrarily introduced by the teacher as little as possible, is of the utmost value. The girls may be left very free to suggest and carry out their own experiments, the class being pulled together from time to time by discussion, summarising of results, and formulation of fresh problems. Variety of method will enable different members of the class to make their own individual contributions to the discussion, and excellent practice in clear exposition may be given by allowing one member who has performed a particularly useful experiment to demonstrate to the whole class and be questioned by the others.

III. *Ages* 14 *and* 15.—As adolescence progresses the mind rapidly expands, and more or less consciously craves wide horizons and broad and generous views. Very simple astronomy, giving some idea of our present knowledge of the Universe and how it has been attained, may be made a most fruitful and stimulating study at this stage. While it must be in large part didactic, it can be taught in such a way that the pupils' own observations, supplemented by diagrams and lantern slides, are used as the groundwork, and the gradual accumulation of observed fact and consequent modification of opinion can be appreciated. An historical treatment is at the same time both helpful to a clear understanding and very rich in human interest.

The following practical work can easily be done by girls of this age, in a school situated in a district not too liable to fogs, if the work is begun in the autumn term. The observations must of necessity be made out of school and must constantly be discussed and checked in class.

1. Identification of the chief constellations; observation of the fact that the fixed stars and constellations keep the same relative position but trace out a circle round the Pole Star complete in twenty-four hours; and that the whole scenery of the sky shifts its position as the seasons progress.
2. Identification of such planets as may be visible; the keeping of careful charts to show the apparent movement of one which moves in a larger, and one which moves in a smaller, orbit than the earth.
3. Observations on time of rising and setting, position of rising and setting, and path across sky of sun and moon.
4. Phases of the moon.

With a small telescope or even very good field-glasses the work can be greatly extended, the nebula in Orion which can just be detected by the naked eye can be found with certainty; the surface of the moon can be studied; the moons of Jupiter can be found, their movements observed; and the fact discovered that whereas the planets can be magnified to appear as discs, the fixed stars cannot.

It is important that the observational work should get well ahead of the lessons which deal with its interpretation, and there is no difficulty in this as at first a good deal of help will have to be given in suggesting points for observation, in criticism of charts, and so forth. Early ideas with regard to the earth, sun, and stars may be described, and possible interpretations of the girls' own observations of the apparent movements of the fixed stars and of the sun discussed. It is important that, at the outset, they should realise the possibility of the movement being regarded as *either* real *or* only apparent, and what the acceptance of either theory would involve. They are then prepared to follow with zest the interpretations given by Ptolemy, Kepler and Copernicus, to sympathise with those who still doubted the real movement of the earth, and to be thrilled at the discovery of the parallax of some of the fixed stars. The scope of the course must vary greatly with the ability of the class and with its mathematical knowledge, but it must not only deal with the solar system, but give an idea of the magnitude of the Universe as a whole.

Theories of the origin of the solar system, the history of the earth and its movements, may lead naturally to a discussion of the seasons, of early modifications of the earth's crust, and of the great wind belts.

Such a course as this may run concurrently with a course of experimental work on light, the two sets of lessons being constantly linked together. Very simple experiments showing propagation of light in straight lines, formation of shadows, reflection and refraction will lead on to the study of the eye, and of optical instruments and their use in the observatory. Colour, the wave theory of light, and means of measuring the velocity of light can also be simply dealt with.

IV. *Ages* 15 *and* 16.—During the last two years of the general school course the pupils should be introduced to some of the theories which dominate scientific thought at the present day. They should realise how great theories grow—the industrious collection of data, the leap forward of some master-mind to grasp the deeper truth which underlies and unifies the apparently disconnected facts, the laborious process of verification. (*a*) The object of the first term's work is to bring forward the wide conception that all forms of energy are convertible one into another, and that the great mechanical devices which have been invented are methods of converting the forms of energy into the most useful kind for any special piece of work. It may also form an introduction to the study of magnetism and electricity and show how the electric power used in every-day life is generated. For example, it is quite easy to measure the mechanical equivalent of heat, to show how chemical energy can be used to generate electric energy, and to show how electric energy can cause chemical change. In the study of the dynamo, magnetic and electric energy can be shown to help each other and to produce heat, light, and mechanical work. This will lead to a discussion of the working of electric trams, the production of electric light, and of much else. (*b*) The object of this part of the course is to obtain experimental results which lead on to an understanding of the general theories with regard to the constitution of matter.

The experiments can be made to develop in a logical sequence starting from the study of air and the oxides. They can be carried out both qualitatively and quantitatively, leading to the knowledge of the quantitative nature of chemical action and also to the properties of many substances—*e.g.*, acids, alkalies, and salts. Equivalent weights of some of the elements may be found by simple but accurate work.

A possible arrangement of this experimental work is as follows :—

1. Chemical changes caused by heating substances in air.
2. Chemical changes due to heating substances out of contact with air.
3. Chemical changes due to the action of substances on each other.

When new substances are discovered their properties can be investigated and the history of the discovery in many cases given. .

An important bit of work which should not be omitted in a course of this kind is the application of chemical properties of substances used in everyday life—*e.g.* the softening of water, the preparation of explosives and fertilising agents, the comparison of baking-soda and washing-soda, the manufacture of matches, &c. But these will be side issues.

But collection of experimental results and a discussion of the explanation of these will give rise to an historical treatment of the molecular and atomic theory Dalton's work being dealt with. The newer theories of the constitution of matter and their bearing on the older theories may then be discussed. The theoretical explanation of many results obtained in the early part of the course now becomes evident, and facts which had hitherto appeared disconnected and comparatively meaningless are suddenly seen to be intimately connected and interdependent; a new mental outlook is reached which both transforms the view of knowledge already obtained and suggests fresh problems to attack.

V. *Ages* 17 *and* 18.—No girl should leave school without some acquaintance with the laws of health based upon a knowledge of the working of a living body. It is preferable that this should be given at a late stage in the school course, both on account of the greater maturity of mind and body which has been attained, and also because sound elementary knowledge of physics

and chemistry is a necessary antecedent. It is best to put such a course between the years of 17 and 18, and it might well be given to all at this age, even if specialisation has begun; where, however, the majority of girls leave when they are about 16, some part of it at least should be allowed to run concurrently with Science lower down the school. It should, if possible, be prefaced by a course of general elementary biology, and in any case as much experimental and observational work should be introduced as will give the girls an understanding of the metabolism of a green plant, a fungoid plant, and an animal, transformation of energy being dealt with as well as transformation of matter, and the interdependence of the three types being clearly brought out. The actual processes in the human body may be dealt with more in detail, the work being given a definitely human trend and used, not only to instruct the girls in personal hygiene, but still more to give some knowledge of the social problems of the present day. Thus the nutrition of the body leads directly to a consideration of dietaries and to the effect of an insufficient or badly balanced diet, and this especially in the case of growing children. The function of respiration will lead to a consideration of methods of ventilation and to the harm inevitably resulting from lack of ventilation and from overcrowding. This will be followed by some consideration of present housing conditions in town and country, the powers of local authorities in the matter and steps already taken for improvement. The functions of nerve and brain lead to the influence of narcotics and stimulants and also to the study of fatigue. An account of the growth of legislation with regard to work in factories and to child labour naturally follows.

This last course goes considerably beyond the work usually undertaken by the Science Mistress, but it is very valuable that such questions should be studied in a scientific manner and with a sound scientific background. It is of the utmost importance that the general mass of citizens shall learn to think more biologically on such questions, and this link between live human interests and their scientific studies is invaluable for the girls.

In every school course much is necessarily omitted, but it is understood that voluntary work done in connection with school societies will supplement the laboratory teaching to some extent. Thus through a Field Club may be given familiarity with common plants and their habitats, or, again, a knowledge of the geological structure of the neighbourhood with its effect on scenery and on history.

VI. Scheme of Science Work in a Public Secondary School for Girls.

By Lilian J. Clarke, formerly Senior Science Mistress, James Allen's Girls' School, Dulwich.

The following scheme of science work has been thought out and adopted in a large secondary school for girls, but it is not put forward as one to be followed by all. Each teacher must herself decide what is best suited to the special conditions of the school in which she works. The school in which this scheme is followed is an endowed day school containing nearly 400 girls, who are allowed to enter at the age of seven, and may stay until they are nineteen.

Special permission is needed for girls to remain after they reach the age of nineteen.

Post-matriculation work in botany, chemistry and physics is taken by some girls who enter for the Higher School Examination and the Intermediate Bachelor of Science Examination of the London University, but only details of the general or pre-matriculation science course are here given.

For many reasons great value is attached to the study of botany. It was felt, however, to be so essential that all girls should have some knowledge of physics and chemistry that for many years half the time given to science in the three forms of the Middle School has been allotted to elementary physics and chemistry, and half to botany.

Every girl who passes through the school studies elementary physics and chemistry for three years, and now has the opportunity of studying chemistry for two more years in the pre-matriculation course.

Botany is studied in most forms. The aim throughout is for the work to be thoroughly practical; the girls have, therefore, to make their own experiments. After experiments have been carried out the results obtained by each girl are received and tabulated, and conclusions are then drawn from these results by the whole class.

No text books are used in botany in pre-matriculation forms, but each girl in the Upper Forms possesses a small Flora.

Plants are studied mainly as living things by means of observations and experiments. Drawings are made from actual specimens and experiments, and not from drawings on the blackboard.

Microscopes are not used by girls taking the pre-specialisation science course, except in the highest classes, where the structure of a green cell, a stomate, and a leaf are studied.

Great help has been derived in the study of botany from the Botany Gardens, which have been gradually made in response to the needs of the botany teaching in the laboratory. As a rule, two girls are responsible for a garden; and every year the girls change their gardens. The work in the Botany Gardens each year is determined by the nature of the work in the laboratory, and the indoor and out-of-door work are closely connected. As far as possible the girls choose the gardens for which they will be responsible.

No time is allowed in the actual school hours for gardening: the girls look after their gardens in the mid-morning and mid-day recesses. The work is voluntary, but so many applications are received for botany gardens that the difficulty has been to provide gardens for all who wished to have them. The numbers of girls who had botany gardens in three recent successive years were 270, 281, 288.

The science work of the pre-specialisation period may be divided roughly into three stages, namely:—

Division I.—The work in the younger forms, before a course of systematic science is begun.

Division II.—The work in the middle part of the school, where definite courses of botany and elementary physics and chemistry are taken.

Division III.—The work in two Upper Forms, where botany is studied by all, and chemistry can be taken by every girl who wishes to do so (two of three subjects, chemistry, geography and a second language are taken by every girl).

At the end of the two years' course all the girls take botany in the General School Examination of the London University. Some girls take chemistry in addition.

Division I.

Age of girls, seven to eleven years approximately. Time per week: two lessons of forty minutes each in three classes, and one lesson of forty minutes in the Upper First Form and in the Lower First Form.

The work varies in different years: an account of what has been done in a particular year is given below:—

Land plants and animals in school gardens. Water plants and animals in school gardens. Trees in winter, spring, summer. Study of common weeds, with special reference to the reasons for their success in competition with other plants. Simple descriptions of flowers. Stages in life-histories of various plants grown by the girls in their own plots. Study of fruits in the lane and in the wood of Botany Gardens, and various methods of dispersal of seeds observed in the Botany Gardens and elsewhere.

Study of Plants in Lane in the Botany Gardens.

The girls of the highest class in this section are responsible for the care and development of the lane in the Botany Gardens, and the indoor work for the year is in close connection with the outdoor work.

The plants are examined in spring, summer, autumn, winter. As often as possible the whole plant is taken. Drawings of the plant are made by the girls, and detailed descriptions are given of various parts. In this way roots, underground stems, above-ground stems, foliage leaves, flowers, fruits, seeds and seedlings are studied in a simple way, and practice is obtained in making accurate drawings. Records are kept of the plants in flower in the lane in successive months.

Study of Animal Life.

In addition to the study of plant life described in the previous paragraph the study of animal life is an important part of the work of every class in this division. The

ponds, the lane, the wood and other parts of the Botany Gardens supply a wealth of material. The girls study the life-histories and habits of many animals. Frequently lesson times are spent out of doors, and the animals are studied in their homes in various parts of the gardens at various times of the year, as well as in the class-rooms.

The course includes:—

(*a*) Life-histories and habits of the garden snail, the pond snail, the spider (including the construction of the web), the caddis-fly, the dragon-fly, the water-boatman, the stickleback, the minnow, the frog.

(*b*) Study of bird life. Identification of the bird inhabitants of the gardens by their calls, their songs and their appearance. Examination of nests which various birds have made in the wood and in the lane and have deserted.

(*c*) Study of bees in the garden and in an observation hive.

Division II.

Science in the Middle School—a three years' course. Age of girls, twelve to fourteen years approximately.

A. Elementary physics and chemistry. Time, one hour twenty minutes in each of three Forms.

B. Botany. Time, one hour twenty minutes in each of three Forms.

B. Botany in the Middle School.

1. *Study of Plants in Wood in Botany Gardens.*

The girls have charge of a small wood and study woodland plants.

2. *Study of Trees.*

There has been planted in the gardens an example of every tree common in England; also in the oak wood there are numbers of oak trees and ash trees. With the help of these and twigs given by various people the girls are able to study trees. The following are some of the points taken: Branching (monopodial and sympodial); structure of buds; development of buds; structure of wood as seen with the naked eye; sections of dicotyledon stems and monocotyledon stems as seen with a hand lens; lenticels; experiments to show passage of gases through lenticels.

3. *Pollination.*

The girls have charge of many plots in which they grow plants which they use in pollination experiments. When the plants are bearing flower buds, many botany lesson-times are spent in the garden. Experiments are first made to see if pollen is necessary for the formation of fruit, and the girls themselves usually suggest that control experiments should be made. Experiments are then made to see if self-pollination can take place in various plants. Many different genera are taken, and as many experiments made in each case as time will allow.

In the year 1925, after the girls had made experiments to see if pollen was necessary for the formation of fruit in a certain plant, and were comparing the results they had obtained with results obtained in previous years, they had the records of more than 1,100 experiments to consider before they drew any conclusions.

The girls watch insects visiting flowers, and study the various insects seen: flies (midges, house flies, bee-flies), wasps, bees (hive bees, humble bees), butterflies, moths.

4. *Study of Fruits.*

There are many opportunities for the girls to study and draw the fruits in the lane, the wood, the order beds, and the pollination beds. Many opportunities for the study of dispersal of seeds are also found in the Botany Gardens. The girls find growing in their gardens plants which have not been planted by them; and after the long holidays thousands of groundsel plants have been found in the wood. Dispersal of winged and plumed seeds and fruits by wind, and of hooked fruits by animals, are soon noted. Reference is made to Darwin's observations and experiments on the dispersal of seeds, and many of the girls read the chapter on dispersal of seeds in 'Origin of Species.'

5. *Detailed Study of Seeds and Seedlings.*

Various dicotyledon and monocotyledon seeds are examined and drawn. Experiments are made to see in what gases seeds germinate, and if seeds germinate at all

temperatures. The germination of various seeds is watched, and successive stages in the seedlings drawn to scale.

6. *Classification.*

Before the girls study classification they have become familiar with the characters of many of the British plants growing in the lane, the wood, the heath, the ponds, and the marshes of the Botany Gardens. When the girls are studying natural orders they have charge of the order beds in the garden.

Division III.

Age of girls, fourteen to sixteen years approximately.

A. Chemistry. Two years' course. Time per week, two hours forty minutes for girls who choose to take this subject in addition to botany.

B. Botany. Two years' course. Time per week, two hours forty minutes.

B. Simple experiments are made by the girls to see in what parts of the root and stem growth is most rapid, to find if roots absorb solids, to trace the path of water in the plant, to determine the influence of light, gravity and moisture on the direction of growth of roots, and the influence of light and gravity on the direction of growth of stems.

Experiments are also made to see what gas is taken in and what gas is given off in respiration, and to determine if there is a rise in temperature when respiration takes place. Other experiments show under what conditions starch is formed in a plant, whether a plant gives off water and the weight and volume of water given off by a plant in a certain time

The percentage of ash is found in plants, and the composition of the ash is taken.

Girls can then find out by means of growing plants in food solutions which elements are necessary to the life of plants. Many perennials are grown in normal food solutions, and generations of plants that have never been in the soil have been reared.

Climbing Plants.

The girls compare the rates of revolution of the twining stems of various plants, note the behaviour of tendrils when rubbed, and make many other experiments.

Soil Experiments.

Experiments are made on soils from different parts of the Botany Gardens. Some of the experiments are comparison of the rates at which water passes down through various soils ; comparison of the rates at which water passes up through various soils ; comparison of the rates at which air passes through various soils.

Ecology.

(1) Water Plants.
(2) Fresh-water marsh plants.
(3) Sea-shore plants { Pebble beach. Sand dune. Salt marsh.
(4) Heath and moorland plants.
(5) Plants of an oak wood.
(6) Plants of a corn field.
(7) Meadow plants.

The Botany Gardens include two ponds, fresh water marshes, a pebble beach, two sand dunes, several salt marshes, a heath, a bog, a cornfield, a miniature meadow, and an oak wood, and in these gardens the above plants are studied, and elsewhere when possible. In addition to the study of the structure of characteristic plants in these ecological gardens, many interesting problems arise and original investigations can be made. For example, experiments are being made in the oak-wood to investigate the gradual changes in the character of the soil, in the total evaporating power of the atmosphere, and in the light intensity, as the trees develop more leaves, and observations are being made of the effects of these changes on the ground vegetation.

Note.—Sometimes in the interval between the General School Examination and the end of term some of the girls of Form Upper V, by their special request, study the assemblage of plants and animals floating in the water of the ponds—the freshwater plankton.

VII. Suggestions for a Course of Practical Food Studies.

By Prof. Henry E. Armstrong, F.R.S.

(The following suggestions for a series of practical food studies are very similar in form and purpose to those given in the schemes accepted by the Association in 1889 and 1890. This scheme was offered to the Association, precisely in the form in which it is now printed, at the Norwich meeting in 1907; the Committee of Section L suggested that it should be published in full but this recommendation was not adopted by the Committee of Recommendations. My object was to aid teachers, especially in girls' schools, who desired to develop a logical, comprehensive laboratory course of instruction based upon food materials. At the time I stated that the scheme was not half complete: it needs elaboration, especially on the physical, botanical and biological sides: had the slightest encouragement been given, I should have developed it. Its present belated appearance may perhaps serve to stimulate a few teachers to take up a line of work which is certainly of promise, if only it be pursued in a proper scientific spirit. My desire has been to see a scheme of instruction gradually introduced into girls' education which will make them scientific observers and thinkers in relation to all home matters: if this position were gained, they would stand on an intellectual plane far higher than that they now occupy.)

Study of Food.

At the outset, children might be asked what they know about food—what people take as food—to draw up a list of foods, arranging the different kinds together according as they are vegetable, animal, &c.—to think what infants live on (milk *and* air); what is the simplest food we can just live on when we have teeth (bread and water and air); that if butter or dripping (fat) be added to bread, it becomes improved both to taste and as food; and that bread and butter together with milk and water and air are a thoroughly satisfying food.

After much talking about such matters, they should be led to write simple accounts of what they know or can find out by observation and inquiry about foods under heads similar to the above. It would be well to let them find out what animals generally live on, so that they may understand the distinction between carnivorous and herbivorous animals.

As it is possible to live on bread, air and water, bread may be studied thoroughly as a typical solid food. The answer to the question 'What is it made from?' 'Flour or wheat'—would lead to the further question 'What is flour?' Flour should then be made by each child—practically, as it is still made by savage races and as it was made before flour mills were invented—by pounding wheat in a mortar or crushing it with a rolling pin. The exercise should be carried out seriously and with scrupulous care, each child being made to weigh out a certain quantity of wheat, then to powder or crush it and to separate the flour from the bran by sieving through book muslin; the flour and bran should then be weighed separately and the percentage of each calculated and the loss. A record in writing of this work should be kept by each child.

In the course of the lessons, the production of wheat should be discussed—where and how it is grown. This would give an opportunity for geography teaching and for economic teaching, which might well be utilised: diagrams might be made to illustrate the consumption, yield per acre, price, imports and exports, etc.

The children should be set to examine and describe wheat—the average size and weight of the grains, their appearance, density, etc. They should also be set to grow it—to plant it in different ways, in dry and wet sawdust, in sand and in soil and also just dipping into water on muslin tied over the mouth of a bottle. Wherever possible, wheat should be grown as a crop in the school garden.

A regular account of all that went on should be kept.

To return to bread—having made flour (or before this, if desirable) they should assist in actually making a batch of bread in the kitchen and be led to

observe (not be told merely, by the teacher) and record everything that happened and was done.

Wheat having been thus dealt with, barley and oats and even maize and rice should be studied in a similar way—and cakes should be made by the children (and afterwards eaten) from barley-meal, oatmeal, maize-meal and rice-meal, in order that the value of cereal grains generally as foods might be impressed upon them. A valuable lesson would be given if cakes were made, at this stage, from various kinds of meal.

Study of Flour.

It would be learnt in the kitchen that flour forms a paste which is scarcely sticky when mixed with not too much water, but that more water makes it sticky; the question arises—What does water do to flour? Some things—salt and sugar, for instance—dissolve in water: does flour? Each child should work a pellet of flour paste between its thumb and two fingers under water (in a common tumbler): it would then be discovered that something is washed away from the sticky mass and that at last a peculiar stringy rather than sticky mass remains from which nothing more can be washed away even by running water. From the turbid water in the tumbler, a white solid gradually settles down which is not in the least sticky. The experiment should be repeated on a larger scale by each child with say 30 grams of flour. This should be put into a basin and mixed, by means of a short stout glass rod or stick, with about half its weight of water. The paste should then be kneaded between the fingers under a tap from which water trickles, the washings being collected in a basin over which a square of muslin is spread, so as to catch any sticky particles which may be broken away. When the washings are no longer milky, the stringy mass should be dried by rolling it on the palm of the hand, constantly drying the hand with a towel, just up to the point at which it shows signs of sticking—but no longer; then it should be placed on a 2 or 3 inch square of grease-proof paper and dried in a water oven. When dry it should be weighed.

The washings should be poured into a large pickle-jar or cylinder and allowed to settle. After an interval, as much as possible of the clear liquid should be syphoned off and the residue collected on a filter, dried and weighed.

In this way, the flour would be separated into *gluten* and *starch* and a fair estimate would be made of the amounts of each.

On treating barley-meal, oatmeal, maize-meal and rice-meal in the same way, it would be found that they did not yield the sticky substance (gluten) when kneaded with water. One reason why wheaten meal is more suitable for kitchen purposes than other kinds of cereal meals would then be made clear.

Study of Starch.

Starch is in common use—for what purpose? For stiffening articles of clothing—collars, cuffs, shirt fronts, etc. What is it like and how is it used? Examine samples and describe it. Prepare a quantity for starching by mixing . . . grams with . . . cubic centimetres of cold water, using your forefinger to stir them together, then pour the paste in a thin stream into . . . cubic centimetres of boiling hot water contained in a dish or saucepan of suitable size, stirring constantly, as you pour in the paste, with a wooden spoon or rod. Set the liquid aside to cool but cool a portion rapidly in a test tube under the tap. Taste it and solid starch. Describe the appearance of the liquid and everything that happens to it as it cools. Dilute a small portion considerably, to a known extent; then add a drop or two of a solution of iodine to a litre of the diluted liquid. You will thus become acquainted with the characteristic test for starch.

Carry out a like series of operations with the starch you have prepared from flour.

Examine starches from different sources under the microscope—note the effect of iodine.

Test arrowroot, sago, tapioca, macaroni, vermicelli, for starch; also try if you can extract gluten from these materials.

The presence of starch, in considerable quantity, in important food materials, having been thus established and something learnt of its properties, the part it plays in cereal grains may be considered.

What happens to the seed when it germinates and a plant grows out of it? Some information will have been gained already on this point. The gradual disappearance of the starch will have been noted. By tasting grains which have been soaked in water and then kept for various periods, the development of a sweet taste will be noticed. Malt may then be introduced and an account given of the way in which it is made and what it is used for. Malt should be made by steeping barley in water during . . . . hours, then keeping it and allowing it to germinate until the young plantlet is about . . . . inches long, after which it is dried at a temperature not exceeding . . . . C. The appearance of the starch grains of the malted and unmalted barley should be noticed under the microscope. Then equal quantities of barley and of malt which have been ground in a coffee mill should each be mixed with about . . . . times their weight of ordinary water and the mixture allowed to stand . . . . hours. It would then be discovered that in one case the starch disappears. The liquids should be examined and the weights of equal volumes (the relative densities) contrasted with that of water. Known quantities should be evaporated in weighed dishes on the water bath, in order that the weights of matter in solution might be determined. It would thus be discovered that the starch is changed into a soluble sugar-like material and the disappearance of the starch from the seed during germination would be explained.

Foster's 'Primer of Physiology' (Macmillan & Co., Ltd., 1s.) might be studied at this stage with advantage and the nature of the stomach and intestines made clear. At some time also the stomach and the intestines of a freshly killed rabbit should be laid bare before the class and their character and arrangement fully explained.

The children might then be asked—What happens to the starch in our food? What is done with it?—It is first chewed in the mouth and becomes mixed with spittle or saliva, is it not? Does this latter produce any effect on it? Try! Spit freely into a test tube half full of solidified starch paste prepared as directed; mix the starch and saliva well together with the aid of a light wooden rod which you have made for the purpose. Plunge the tube into a water bath kept at about . . . C.; examine it at intervals. Repeat the experiment but first spit into the test tube and then plunge it into boiling water; after about five minutes' heating add the starch and digest the mixture: at the same time digest a mixture of starch with similar unheated saliva. Also make comparative experiments in a similar way with unboiled and boiled malt-extract.

It would then be discovered that starch is rendered soluble by something which is present both in malt-extract and in saliva—something, moreover, which is rendered inactive by heating to near the boiling point of water. This substance has been named *Diastase*.

The importance of the change thus undergone by starch when 'digested' with the aid of the diastase either in malt-extract or in saliva would be more obvious when it is realised that starch *diffuses* with extreme slowness into water and that it does not pass through wet bladder or vegetable parchment, whereas the sugar which is formed from it on digestion, like ordinary sugar and salt, diffuses readily.

Our starchy food is cooked either by baking or by boiling it—what is the effect on the starch of baking and boiling?

When heated in the oven, as in baking bread or pastry, flour is browned and may easily be burnt; but flour is more than starch—what happens to starch when it is heated alone? Study the effect of heat on starch very carefully, at gradually increasing temperatures.

At an early stage, vapour is given off—what does this look like? Steam—that is to say, water vapour. Perhaps the starch was not dry—dry it carefully at a temperature at which wet things are easily dried and repeat the experiment. Vapour is still given off when the dried starch is heated—is it water vapour? How can you find out? What happens when water vapour meets a cold surface? Try! The vapour becomes liquid—it condenses. See if the vapour from starch can be condensed. You find it can and that the liquid is like water—is it water? Would not the discovery that it is water be of interest and importance as an indication that water is in some way contained in starch? Try therefore to prove that the liquid is

water. Heat . . . grams of starch in a vessel from which the vapour can only escape through a cooled tube (a condenser), and when you have sufficient of the liquid contrast it carefully with water.

But water is not the only product on heating starch : as the heating is continued, the starch becomes more and more burnt or charred ; at last, it is converted into a mass of very light charcoal, which easily takes fire and burns away to nothing ! Are not these strange changes—who would suppose that in white starch there are hidden away in some mysterious manner both black charcoal or *carbon* (to give it its Latin name) and water ?

How comes it that starch is useful to us as food—has the presence of carbon and water in it anything to do with its value as a foodstuff ? We certainly cannot eat charcoal as such but what *can* we do with it ? What is it used for ? In England, we no longer use it as fuel, as it is too expensive ; in France and Japan, however, it is still much used in cooking and also for warming rooms. Have you not heard through the newspapers of people being killed by the fumes of burning charcoal ? Does not this show that it must not be assumed, because nothing is seen to escape, that charcoal gives nothing when burnt ?

What does food do for us ? It makes us grow, you will say ! But does it not also keep us warm—may not perhaps the warmth be produced at least in part by the burning of the carbon which is in the starch we eat ? Is not the suggestion one which it is well worth following up—will it not be well to study burning ? What are the things we burn or which we know will burn ? Make out a list.

Combustibles.

From the domestic point of view, our most important fuel or combustible is coal—what do you know of the way in which coal burns—does it just burn when set fire to ? You know it does not. To keep a fire burning, air must be supplied to it ; if a fire be low, it is often restored by holding a newspaper in front of the stove or grate in such a way that a draught of air is forced through the feebly glowing embers —very soon these begin to burn brightly and at any time a fire may be caused to burn brightly by increasing the draught through it : by using bellows, we often make a fire burn up quickly.

Must we not conclude, therefore, that air has something to do with the burning of coal ? Is this true of other combustibles ? Consider what you know and if you cannot produce evidence one way or the other—but such questions should be settled by trial or by experiment, not by guessing.

Under ordinary conditions, we cannot see what happens to the air during burning —suppose you shut up a burning candle with air so that you can watch the air as well as the candle flame. You will probably think of several ways of making such an experiment ; the easiest perhaps is to place a small piece of candle on a block of wood floating on water in a basin and cautiously to invert over the flame a bell jar provided with a stopper which you insert the moment the bell jar is in position ; or you may use a small statuette cover. Noting everything that happens, you see that almost at once the sides of the jar become bedewed ; the flame grows dim and after a time goes out ; at the same time the water rises in the jar, showing that some of the air is used up. It is desirable to paint a line a short way up the jar with Brunswick black, such as is used in blacking stoves, to mark the position of the water at the start. When the jar is again cool, the point to which the water rises should be marked in some suitable way and the capacity of the jar ascertained above this mark and also between it and the lower mark : the amount of air which disappears is then ascertained.

Similar experiments should then be made with other combustibles—spirit, different oils and gas. In every case, the flame soon gives out and some air disappears : less than a fifth. Clearly the air is concerned in the burning—but very partially : does it not seem that it contains something which is active rather than that it is active as a whole ?

Solid combustibles are not so easily dealt with : if an electric current be available, you may fire such substances in air, in a bell jar standing over water, by means of a spiral of platinum heated to redness by the current—in every case air disappears but never quite a fifth. Why does some disappear—is it because it is in some way changed into water vapour which condenses on the jar and on contact

with the water used in shutting up the air in the bell jar? Do all combustible substances give water when burnt? Can water be condensed from the candle flame and other flames? Try the effect of exposing a cold surface (a flask full of cold water) to each. At once it is bedewed but except in the case of the spirit flame it is soon smoked or coated with soot, which looks like charcoal or carbon in a fine state of division—so there seems to be carbon in combustibles, as there is in starch. Although the liquid which bedews the flask looks like water, you have no proof that it is water: as nothing is to be taken for granted, you must burn the several combustibles in such a way that you can collect enough of the liquid from each to contrast it with water.

Having done this, you feel sure that water comes from each of the liquid combustibles when they are burnt in air. What of solid combustibles such as wood, charcoal, coal or coke? It should not be difficult to make observations over fires made with these and to convince yourself that charcoal and coke give practically no water although indications are obtained that it is formed on burning wood and coal.

What becomes of carbon when it is burnt, therefore, remains a mystery to be solved only by further inquiry.

Although there is yet much to learn as to what happens when things burn, it is now at least clear that starch may be burnt with the aid of air and that much heat is given out: knowing as we all do that we must have air to live, may it not be that the air we inhale serves to burn part, at least, of our food, quietly and in such a way that we are kept warm by the process? If so, the fact that air is an indispensable article of food meets with an explanation.

Before taking up fresh subjects, it is worth while to take stock of the knowledge gained by studying flour and starch experimentally: Flour has been resolved into starch and gluten; the latter, however, has been set aside temporarily while starch was being examined. It has been ascertained that although wheaten flour has certain advantages, owing to the peculiar properties of its gluten, other cereal grains give flours which are also mixtures of starch and gluten-like substances; potatoes, however, have been found to consist almost wholly of starch. Starch, it has been discovered, contains both carbon and water, associated apparently in some strange way which altogether masks their ordinary properties. Itself insoluble but convertible into a peculiar jelly-like material (starch paste) by heating with water, starch is changed by diastase (a constituent of barley and of human saliva) into a soluble diffusible sugar. A little reflection will show that these properties give starch its peculiar value. It occurs in the seed of cereals and in the potato tuber—the resting parts of the plants: if it were soluble, it could not well be stored up, and unless it could be rendered soluble by digestion, it could not pass into circulation and serve as food—in fact it has just the attributes which are required of a substance occupying the position it holds in the plant world. Starch is a substance which is easily burnt: in studying it from this point of view, it has been discovered that burning is a process in which air is concerned—not air as a whole but an active portion in it.

The Kitchen.

Books are usually divided into chapters: when the story is carried to a certain point it is broken off and a new chapter is begun, in which some other set of characters is considered. It will be well to leave the study of food for a time and pass to the kitchen, where the stove and fender and fire irons are to be found. All these are made of iron and, like steel knives, must be carefully looked after and kept bright. Why? Why too is so much care taken to paint ironwork out of doors? We use many other metals and leave them unpainted—at most they are tarnished, but iron rusts and spoils. What happens to it—what makes it rust? Water, you say—if water be dropped on the fender and be allowed to remain there or if knives are left wet, rust soon appears. You must not be hasty in your conclusions—you will soon find out if you are that your conclusions are often wrong. If water be the cause of rust, should not iron rust if corked up with water, say, in an ordinary medicine bottle?

Get some bright iron nails (wire or French nails) and try the experiment; at the same time expose some nails in a saucer along with a little water—not enough to cover them. Scarcely any rusting takes place in the bottle, while outside the bottle the nails rust considerably. Why is this—what was the difference between the two experiments? If air were present in the one case and not in the other and in some way play a part, it may be possible by watching the air to find out if it be concerned. Shut some air up over water along with some wetted iron. Some of the air disappears—how much—is the amount definite?—make sure by repeating the experiment several times. What is the remaining air like—is it unchanged air—how will you try? Think of a test. Have you not made a great discovery about air when you take into account what you had previously learnt in your experiments on burning? What will you call this active part of air—may it not, for the time, be called *Fire air*—the air which, in some way, gives rise to fire; or rust air, if you will? In the latter case, however, the name has reference to a less striking property of the air or gas; it is less significant though appropriate in its way. What becomes of the 'Fire air' as the iron rusts—it changes the iron into rust, is it in the rust? If this be so, what must happen as the iron rusts—iron rust, when you handle it, seems to be a much lighter substance than iron (find its exact density as well as that of iron) but is the rusted iron lighter or heavier than the unrusted? Try!

The result of this experiment should leave no doubt in your mind that iron rust is formed by the association or *combination* of the active gas in air with the iron—that it is a *compound* of iron with the active gas. It is clear also, is it not? that in some way the water plays a part—as the rusting only takes place when the air and water act together—what that part is cannot be determined at present, however.

Probably you never suspected that the kitchen range, the fender and the fire irons were in any way to be associated with your food except that they were of use in preparing it—that they could be brought into relation with it through air and water cannot well have entered into your thoughts. Is not the lesson a very valuable one—is it not one that teaches you that no opportunity is to be neglected—that eyes must always be open and willing to see, willing also to send messages to the brain?

Is not the formation of a substance such as iron rust from the metal iron very remarkable? Compare them carefully in every way you can and consider the nature or properties of the two substances. The one, like metals generally, is bright or lustrous when polished and is relatively heavy; it can be bent and beaten and drawn out without breaking—its strength being one reason why it is so useful. Rust, however, is quite unlike a metal—it has no strength and is easily powdered. What does it most resemble, especially when powdered? Red earth, does it not? It may be best described as an earthy substance—in fact, in some parts of our country, in Devonshire particularly, the soil looks just like iron rust and red soils are frequently met with. You may have noticed too that burnt clay is not unlike iron rust. Burn some clay, if you have not.

What is iron itself—is it found anywhere; if not, how is it made? It is well worth while to inquire what is known of the early use of iron and to consider how, probably, the way to make it was first found out. It is made from ironstone—from iron ores as they are called, some of which are very like iron rust and others like hardened clay. It is made from an earth, in fact—by smelting or heating the earth together with charcoal or coke. You know that carbon burns in air—in the active part of it (Fire air) that is to say: does it perhaps associate with the Fire air as the iron does in rusting and does it release the iron in the ore when it is smelted with it by depriving it of Fire air? Questions such as these are not to be answered without further study.

Study of Burning.

As food and fire seem to be closely connected, it may be well now to study fire a little more fully and carefully. How do we produce fire—in the morning when lighting the fire; or at any other time? You say at once—by striking

a match. What is a match?—nothing is more commonly used and yet few know anything about it.

The easily inflammable substance—that which is fired by the heat developed by friction in drawing the match over the rough surface of the box—is *phosphorus*. What does the word mean—what language is it derived from? Phosphorus is made largely from animal bones. From bones, you say: can't we get away from ourselves and our food even in studying the matches used in lighting the fire with the aid of which our food is cooked? Do all things move in a circle?

Phosphorus, you will see, when it is put before you, is a yellow wax-like solid; it is always kept under water and must be handled with extreme care and only kept in the fingers during a short time, as it takes fire very easily and the burns it produces heal with difficulty. Why should it inflame sooner or later when taken out of water and not in water? Does this behaviour suggest anything to you? If so, make an experiment to verify your idea. What has this experiment taught you—does it not serve also to bring the match more closely into relationship with the iron stove than you before thought to be likely?

Very little phosphorus is used in matches—how does it burn alone? Carefully dry a small piece, first on a duster and then on porous paper, place it on a brick or tile and touch it with a warm wire: at once it takes fire and burns brightly; as it burns, dense white smoke is given off. Try to stop the smoke from escaping by covering the burning phosphorus with a glass shade. Note what happens—describe the product.

In burning other substances, you have found that the air is concerned—that, in part, it is 'burnt' as well as the inflammable substance: is the air concerned in the burning of phosphorus? Try.

As the phosphorus takes fire so very easily, will it not be well to try to burn it alone to make sure that the air is concerned? It is possible to remove the air from a vessel by means of an air pump. Let us put a piece of carefully dried phosphorus into a strong globular flask, provided with a tightly fitting rubber stopper to which a glass tap is fitted: having exhausted the air by means of the pump and closed the tap, let us now cautiously heat the flask, where the phosphorus lies, over a small flame, sufficiently to melt the phosphorus: nothing happens. Now let us repeat the experiment with a strong flask full of air closed by a simple rubber stopper: the phosphorus takes fire but soon ceases to burn and apparently some remains unburnt. There was not much air in the flask—was any or all of it burnt along with the phosphorus? Think what happened when the phosphorus was exposed in air over water. What then will happen if the stopper be withdrawn from the flask while the neck of the flask is under water? See!

It is clear therefore that whether it be merely exposed in air or burnt in air, the phosphorus kills, as it were, very nearly one-fifth of the air—its behaviour is much like that of all other burning substances, except that, to be precise, it is more like that of iron—which also gives a solid product, unlike the other substances which were burnt. But the air behaves alike to iron and phosphorus, seeing that one-fifth disappears under the influence of each. This fact would seem to indicate that the same constituent of the air is concerned in both cases—try to place this beyond doubt by experiment.

How does the phosphorus act—does it associate with the active gas in air—is the white snow-like product a rust? How will you ascertain? You must prevent the smoke from escaping, must you not, if you wish to contrast its weight with that of the phosphorus—how will you do this—how is smoke to be held back or screened off—what is a respirator used for? Very well, then: fit up a suitable respirator to prevent the smoke from escaping from a tube in which phosphorus is burnt.

From the result, it is clear, you see, that the phosphorus and iron behave alike towards air, withdrawing and combining with the same proportion—very nearly one-fifth; and it seems probable, does it not, that this one-fifth about (the Fire air, as we have called it) is a special constituent present to this extent in air? You have thus discovered what of air—that air is a mixture of at least two kinds of air, have you not?

Where does the fire come from? It seems to have its origin in the act of association, does it not? What becomes of the fire or heat produced on associating phosphorus with Fire air? It escapes, does it not? The flask in which the phosphorus is burnt becomes unbearably hot in places but soon cools—the heat is soon lost : does it, the heat that is lost, weigh anything? Try!

You have thus made the discovery—the wonderful discovery—that fire is weightless—something unsubstantial, unmaterial—but consider what strange changes attend its production : the metal iron and Fire gas give rise to the earth-like rust; the phosphorus and the Fire air to phosphorus snow; the various ordinary combustibles, whether gaseous, liquid or solid, seem to afford water and something which has escaped our notice hitherto, which probably therefore is an air-like or gaseous substance : but if so, it must be quite soluble in water, must it not, as nearly one-fifth of the air disappears when the various substances are burnt in it? Stay, now, do you know that all substances burn at the expense of one and the same constituent of air? Will it not be well to try whether, in all cases, the inactive four-fifths left after exposing iron or phosphorus in air be inactive also towards all ordinary combustibles? In this work, nothing must be taken for granted. Also do you know that when iron and phosphorus 'rust' in air heat is produced as when phosphorus actually burns in air? Is heat given out when the phosphorus is merely exposed in air? Make the experiment in a really warm room, using a thin rod of phosphorus lashed to a wooden rod.

You thus obtain evidence that even when the Fire air is absorbed slowly, heat is produced, and you can believe that whether the phosphorus burn visibly or not is merely a question of the rate at which the change takes place—whether the heat have time to get away or not.

You may ask : Is the rusting of iron a case of slow burning? The reply is—Can iron burn? How were fires lighted before matches were known—how were guns fired before percussion caps were invented? With the aid of a flint and steel. Try the effect of striking pieces of flint and of iron together. If you can find a smithy, watch the blacksmith at work at his forge; still better, go to a steelworks where iron is rolled into bars and plates. Examine a new horseshoe and contrast its surface with that of one which has been in use. Examine the ground near the smith's anvil. Heat a piece of bright iron to redness for some time and notice the effect; then prepare some coarse iron filings and heat them in a muffle furnace on a clay support, weighing them before and after heating.

Having thus ascertained that iron can be burnt, you will be prepared to regard rusting also as a case of slow burning—whether it rust slowly or burn rapidly, it equally combines with Fire air and becomes converted into a pulverulent, earthy substance : a red earth in the one case, a black earth in the other.

You will perhaps ask—do other metals burn? Do other metals give earths when burnt? Metals are so commonly used in household practice that it will be well to know something about them. Copper vessels are commonly used—does copper combine with Fire air and burn? Try! Does lead, does zinc, does tin? You can easily try. Magnesium, in the form of ribbon, burns very easily—study the change carefully. Try also if silver can be burnt.

Having previously contrasted iron with iron rust by determining their densities, it will be well in the case of other metals to contrast each of the products with the metal from which it is formed and to draw up a tabular statement of the results arrived at. It will be well, instead of making all the substances, to inquire if you cannot obtain the various burnt metals and at the same time to collect information as to the use that is made of them and of their market value in comparison with that of the metals. At the same time, it will be well to inquire how the metals are made.

Such a comparison affords most instructive results—in every case, the metal affords an earthy product : some of the earths are relatively light, others heavy—some are coloured, others colourless; how do they behave towards water—have they any taste?

All this time, the snow formed on burning phosphorus—which is certainly not at all like a metal—has been left out of consideration : it should therefore

be compared with the earths formed from the metals. You have already learnt that its behaviour is somewhat peculiar—what became of it when the phosphorus was burnt over water? If you did not notice, repeat the experiment. What happened to the snow which fell on the tile when the phosphorus was burnt under the glass shade? Can the snow be kept in a closed bottle? Has it any taste?

It seems then that earths are produced when Fire air is combined with metals—what other combustible substances yield when combined with it is not yet clear: only in one case, that of phosphorus, have you learnt that a sour or acid-forming substance is produced.

To understand what becomes of food when it is burnt, it is clearly desirable to extend the inquiry—carbon is certainly not a metal and there is no evidence yet that any earthy substance is formed when it is burnt, apart from the small quantity of ashes which remains.

Has it not struck you as remarkable, when you were hearing of the ways in which the various metals were made, that in most cases carbon in the form of anthracite, coal or coke, was used to separate the metal? The metallic ores are mostly earthy substances and most of the metals are converted into earths by roasting them in air—what then is perhaps the nature of the action which the carbon exercises in separating the metal? Will it not be well to try experiments with the earths prepared from the metals or with those which afford metals and to heat them with charcoal? In some cases, you obtain the metal easily—what else? Nothing solid or liquid—perhaps an air or gas is produced. Try; if one be obtained, collect it and examine it in comparison with air by determining its density, &c. Then see what happens on burning starch in a similar way. After these experiments, there can be no doubt that the carbon in starch is of value as a combustible.

Plants and Soils.

Although our food is partly of animal and partly of vegetable origin, excepting fish, poultry and game, the animals we use as food are entirely vegetable feeders: directly or indirectly, therefore, we are dependent on plants for our food—we could not live on air and water and the soil as they do. The knowledge gained from the experiments you have made enables you already to ask of what use is air to plants—do they breathe as we do? They are not warm, as we are—nevertheless, it may help them to burn some of their food slowly. What is their food—where do they obtain the carbon which is contained in starch and which we must suppose is a chief constituent of plants, of wood and of all vegetable materials, as they all give more or less charcoal when heated sufficiently strongly? The use to them of water we can understand to some extent, as they are full of watery juices, like ourselves. Of what use to them are roots—do they suck all their food out of the soil with their aid? As roots are peculiar to plants, it does not seem unlikely that this is the case. Considerations such as these make it desirable to know something of the soil.

To grow plants properly, they must be cultivated; all soils are not equally good. What is soil? The surface crust of the earth. Even in those regions which consist of hard rock, the surface is usually soft soil formed by the gradual decay of rocks under the influence of the weather. What kinds of soft rock or soil do you know—what kinds of hard rock?

The soft soil everywhere is either sand or clay or a mixture of these (loam). You probably know both kinds and are well aware that they are very different, but it is better that you should examine them carefully. Take . . . grams of each, examine them—if possible with a magnifying lens; describe them, contrast their behaviour, also their behaviour with water, both when wetted with it and when stirred up with a considerable quantity. Afterwards examine some garden and field soil and see what you can separate by stirring up the soil with water and decanting off the water before the lighter particles have settled.

The separation of sand from clay is always going on in rivers and in many

places along the sea-coast, and it is on this account that sand-banks are formed in rivers and that the sea-shore more often than not consists of sand.

Sandstone.—Sand is found in many places mixed up with pebbles of various sizes—how are such rounded pebbles produced, do you suppose? If you have been on the sea-coast where there is a shingle beach, you will probably be able to account for the rounding of the pebbles. What are gravel pebbles like inside—do they in any way resemble sand?

Hard rocks are of frequent occurrence which are obviously formed of sand particles stuck firmly together—these are commonly known as sandstones; they are usually coloured more or less—yellow, brown or even bright red. Flint, chert and quartz are solid, almost glass-like rocks, which when broken into small pebbles give a material like sand.

Clay.—In many places, soft rocks are found which are more or less easily split up into slabs or sheets; these are known as shales or slate rock. If the fine powder formed by grinding them be mixed with water, it forms a more or less sticky, clay-like mass.

Limestones.—Rocks which yield lime when burnt are very generally met with together with sand and clay; they vary much in character according to the district, some being soft like chalk, others hard and crystalline like mountain limestone. The limestones are always full of fossils; chalk under the microscope appears to consist almost entirely of shell-like remains.

Igneous rocks.—Sandstone, clay and limestone are known as sedimentary rocks—there being complete proof that they have been deposited as sediments from water.

A fourth class of rock includes all rocks which have cooled down from the fused state. Granite is one of the most characteristic of these rocks and is well known, as it is much used as an ornamental stone for building.

Everyone should be familiar with these common rocks and take some interest in their history and the wonderful story they tell when properly interpreted: this study should be made almost entirely an outdoor occupation.

Nature of Limestone.

In studying starch, we have taken into account things which were known about it and have based experiments on these; the results have enabled us to arrive at certain conclusions; our discovery that starch contains carbon and perhaps water was based on the study of the changes which it undergoes when heated and when burnt in air. We were led on to study the changes which metals undergo when burnt and to discover that the earthy substances into which they are converted are compounds of the metals with Fire air. We were able to take away the Fire air from the metal in some of the earths by means of carbon. In every case a change was effected—we arrived at our knowledge of the nature of the subject by studying a change in which it was concerned. Can this method be applied to the study of soil materials—in appearance they resemble closely the earths obtained by burning metals—are any of them known to undergo change in any characteristic way? What is done with sand? It is used along with lime in making mortar and when fused with soda forms glass.

Clay in admixture with sand is used in making bricks and when burnt with chalk yields cement.

Limestone when burnt is changed into lime; in the form of soft chalk or preferably of lime, it is applied to the soil as manure.

Apparently, all undergo change; limestone, however, is changed when heated alone and therefore seems to offer the simplest case for study.

A series of experiments might follow, on lines like those indicated on pp. 355-359 and 444-448 of my 'Teaching of Scientific Method' (Macmillan & Co., Ltd.), leading up to the discovery of the compound nature of limestone. Limestone has thus been resolved into two substances—solid lime and a gas: although not itself an earth like any of those formed on burning metals, the lime obtained from it is very similar in appearance at least to the earths which are formed from some of them; as to the gas, being colourless, it is not easily compared with other gases. What are the properties of the gases you have dealt with thus far? Of the two gases in air, one, you know, promotes combustion, the other does not; the gas you obtained by burning carbon by

means of red lead and copper scale was heavier than air and more soluble in water than air and a taper would not burn in it. On testing the gas from limestone, you find that it resembles the latter gas rather than air. You have also discovered that the gas from limestone can be reconverted into limestone stuff Does the gas prepared from carbon at all resemble it in this respect? On making the experiment you find it does; indeed you cannot distinguish between the two—they are the same material. Think what a momentous discovery you have made! That carbon is an important constituent not only of vegetable and animal matter but also of the earth limestone—it seems to be everywhere, in some cases in an unburnt, in others in a burnt state. You may ask, how comes it to be in limestone—in a burnt state? What is limestone composed of? Chalk, the form which you have examined, consists of the remains of minute shells—shells are of animal origin—are all shells alike in composition? Such reflections should lead you to study a variety of shells, salt-water, freshwater and land shells, the shells of birds' eggs.

In the course of the experiments with limestone, it has been discovered that the gas which is a constituent of limestone stuff is present in minute proportion in the air. How does it get there? You know that it is formed by the combustion of coal, wood, &c. As we are kept warm by our food and it is probable that it is more or less burnt up in our bodies and that the air we breathe in is used for the purpose, may it not be that the gas is also given out by us? Try to find out by contrasting ordinary air with expired air. See also if the gas be given off by animals, such as mice, by caterpillars feeding on green leaves, by snails, &c., by keeping these under a bell jar through which air is passed after scrubbing it free from the gas by means of lime. Also endeavour to find out if air be concerned in the germination of seeds by ascertaining if they germinate in air over water and whether the air be affected and also whether as germination takes place the gas be driven off.

Study of Acids.

Are you not surprised that you have been able to find out so much—and especially that whatever you do you are always led, sooner or later, to discover something of interest in relation to yourselves? No doubt you are anxious to continue your inquiries now that you begin to understand what wonderful changes are going on everywhere.

The gas obtained by burning carbon resembles the product from phosphorus and differs from the earths derived from the metals inasmuch as they are both formed from substances which are clearly not metals—yet as one is a gas and the other a solid they are not directly comparable as are the products from the metals. Have they any property in common? What property is characteristic of the phosphorus snow? Its taste, is it not? Has the gas an acid taste? Try! Acids stain coloured clothes, do they not? The colours of flowers are very sensitive—make coloured solutions from a variety of flowers and see whether they are affected by solutions of the two substances which you are studying and by the common acids. You find that the product from carbon has only a weak action but it seems to act in the same direction as the acids. Things which are similar may sometimes be substituted for one another, may they not? You know that limestone contains the gas which is derived from carbon and that the common acids in some way turn the gas out—will the acid product from phosphorus have a similar effect? Try! You thus discover that the two substances have similar properties, although not alike in strength —both are acidic substances. Are there any other non-metallic combustibles which you can study to ascertain if they yield acidic products? Although sulphur matches are not much used nowadays and almost the only occasion when sulphur is used in the house is when it is put into the dog's water, you perhaps know the smell of burning sulphur. Burn some sulphur, pass the fumes into distilled water; taste the solution, test it with colours and add some chalk to it. You thus become acquainted with a third acidic product of combustion derived from a non-metal: the probability that non-metals form acid compounds and metals earths when associated with Fire air is therefore increased. Years ago, when it became desirable to give significant names to substances, the great French chemist Lavoisier introduced the name *oxygen* for the gas

we have spoken of hitherto as Fire air; it retains this name to the present day, except among the Germans, who call it *Sauerstoff* or sour-stuff—the stuff of which acids are made; this too is the meaning of the word oxygen, which is derived from two Greek words, *oxus*—acid and *gennao*—I produce. The compounds of oxygen are termed oxides and it may be mentioned here that the terminal *ide* is always restricted to substances which like those in question consist of only two others.

Thus far you have been led to conclude that there are two kinds or classes of oxides—metallic and non-metallic: oxides of metals and oxides of non-metals. The latter it is found are acidic—they form acids when dissolved in water; except that the former are more or less earth-like in appearance, nothing has been observed which seems to be characteristic of these oxides as a class. Have you not noticed, however, that lime resembles the metallic oxides—is it perhaps a metallic oxide—what is characteristic of it: is it not its power of combining with carbonic gas and other acidic oxides—if then it be a metallic oxide, the metallic oxides generally may be expected to resemble it in combining with acidic oxides, may they not? You have found that not only is limestone acted upon by the common acids (muriatic acid, aquafortis and vitriolic acid) but lime also: in what way are they acted upon—comparing the effect of heat on limestone with that produced by acids, does it not seem that the lime in it is acted upon by the acid and the carbonic gas just let go? Does it not therefore seem desirable to study the action of the common acids on the metallic oxides generally in comparison with lime?

But you will ask: what are these acids: how are they obtained? Surely, if we are to use them, we should know something about them.

[Sketch history of the discovery of oil of vitriol—pyrites used by palæolithic man—decay of and conversion into green vitriol and rust—distillation of green vitriol, production of oil of vitriol—strong sulphur smell, pyrites combustible, burning like sulphur but giving rust-like earth as well—preparation of vitriolic acid by burning sulphur, later with the aid of aquafortis.]

Knowing what happens to sulphur when burnt, you will at once reason that vitriolic acid is in some way connected with the oxide you have prepared from sulphur—but you are told that it is formed from this oxide with the aid of air, water and aquafortis; or nowadays by passing the gas formed by burning sulphur together with air over heated finely divided platinum. Suppose you try this experiment.

You will now realise that vitriolic acid consists of sulphur, oxygen and water and that it is derived from an oxide which contains more oxygen than is contained in that formed on merely burning sulphur in air; this latter is a colourless gas, whilst the former is solid and forms a dense white smoke. To distinguish the two oxides, one is called sulphurous oxide, the other sulphuric oxide; whilst the acid formed from the one is called sulphurous acid and that formed from the other sulphuric acid. You know that you can associate sulphurous oxide with lime and that you can displace carbonic gas from limestone by sulphurous oxide and also by phosphoric oxide; as you also know that sulphuric acid acts on limestone, you will be prepared to argue that sulphuric oxide can also combine with lime. Phosphoric oxide has proved to be stronger than sulphurous oxide—try whether sulphuric or sulphurous oxide be the stronger, in a similar sense.

Contrast sulphurous with sulphuric acids. The fact that sulphuric oxide proves to be the stronger is clearly of interest in justification of the name sour-stuff or oxygen: the stronger and more pronounced acid being that which contains the major proportion of oxygen.

Aquafortis.—There is no doubt that, in early times, as soon as the alchemists found a new substance, they tried its effect on all the substances with which they were acquainted. In this way, when they discovered oil of vitriol, besides finding out more or less by accident if not by carelessness that it was very corrosive and destructive of their skin and clothes, they probably very soon tried what action it would have on substances such as nitre or saltpetre and sea salt. The former often appears in the form of crystals on the soil in the neighbourhood of manure heaps; saltpetre occurs in large quantities in Chili in

certain districts where there is no rain to wash it away. Both kinds of saltpetre are very valuable as manures. When vitriolic acid is added to saltpetre and the mixture is gently warmed in a retort, a very volatile and acid liquid distils over, the retort becoming full of brownish vapour. This liquid is very corrosive, staining the skin a deep yellow. Of course, the alchemists tried the action of this acid on everything at hand, metals such as gold, silver, copper, lead, tin, zinc and iron, finding that it dissolved all but gold: as it was much stronger than the other acids they knew, they called it aquafortis. To the present day, the jeweller uses aquafortis to distinguish spurious from real gold.

Aquafortis—or nitric acid as it is called on account of its formation from nitre—you have learnt, is used in converting sulphurous into sulphuric acid; it must therefore be capable of giving off oxygen and must contain an oxide. Nitre, or villainous saltpetre, as Hotspur calls it in Shakespeare's 'Henry IV.,' has been used for centuries past in making gunpowder—a mixture of charcoal, sulphur and nitre; also in fireworks. The modern explosives—gun-cotton and nitroglycerin—are also made with the aid of nitric acid. What happens when gunpowder is fired—in what way do charcoal or sulphur and nitre interact? Try to find out.

Muriatic acid.—We get back to the kitchen and our own food once more when we come to salt. Oil of vitriol acts upon it at once—fizzing takes place and an acid fume escapes—spirit of salt, the old alchemists called it. They were clever enough to find out that this fume is very soluble in water and the solution is known to the present day by the oil-and-colour man, the plumber and in kitchen regions, as spirit of salt. It is used in cleaning and removing scale from baths, closet pans, etc. You will find that it is very acid and that it stains the clothes but is not corrosive like oil of vitriol and aquafortis. The plumber uses it in soldering, after 'killing it' with zinc—everyone should learn to solder and it may be worth your while to take the hint given by the plumber and see if you cannot follow up the clue. What is the action of the oil of vitriol on the nitre and salt? You know that it displaces the carbonic gas from limestone stuff—is its action on the salt and nitre a similar one—are they comparable with limestone stuff?

The zinc, you find, is readily acted upon by the muriatic acid—examine the product and compare it with similar substances which you have prepared previously; it will be well to fit up apparatus which will enable you to prepare it at will, at any desired rate. Contrast it with coal gas and determine very carefully what is formed from it when it is burnt.

When this inquiry is complete, you should recognise that you have made a discovery of the greatest importance with reference to your previous work and to the nature of foodstuffs such as starch. Again, you have an illustration of the fact that information is to be gained from the most unexpected quarters—who would suppose that the plumber could help you to determine the composition of starch?

Nature of Water.

You believe that you have obtained this clue to the composition of water—that it consists of the gas which is called water-stuff or hydrogen (because it affords water when burnt) and oxygen: as you know that all other things which you have burnt combined with the oxygen. Still nothing must be taken for granted in our work: it is possible that the oxygen in air is not alone concerned: cannot you devise some method of using oxygen in a form in which there can be no doubt that if water be obtained it is formed from oxygen and hydrogen alone? How did you burn carbon with oxygen alone?

You are now satisfied that you have established the fact that water consists of hydrogen and oxygen. Is it not worth while to submit the oxides generally to the action of hydrogen? Will you not be able to test lime if you find that they all give up their oxygen to hydrogen? The results enable you to classify the metallic oxides in two groups; although you have not yet solved the problem regarding lime, have you not narrowed it—is it not clear that if it be a metallic oxide it is the oxide of a metal of a particular kind?

Perhaps by studying the action of spirit of salt, which dissolves oxides, it

may be possible to obtain further information of assistance in solving the problem as to the nature of lime. Where does the hydrogen come from which is obtained when zinc is dissolved in muriatic acid? As this is a solution of spirit of salt in water, obviously it might come from the water in the solution, since this is known to contain hydrogen; it might come, however, from the dissolved gas. How shall we decide whether or no this be the case? We must eliminate the water, must we not? Try the experiment without water.

There are still two ways possible in which the gas may be formed—it may be present either in the metal or in the gas. Can any argument be adduced in favour of the one view or the other? Zinc oxide is produced on a large scale for making white paint (zinc white paint) and it should be possible to learn by inquiry if water be formed on burning the zinc; if not, the experiment must be tried.

As there is reason to suppose that the hydrogen is contained in the spirit of salt, it is probable that the zinc displaces it, combining with whatever is associated with the hydrogen. How does the oxide behave towards the acid—like lime? It dissolves quietly. What then becomes of the hydrogen, supposing this to be in the spirit of salt—is not its disappearance to be accounted for, if it combine with the oxygen in the oxide? The product in solution will be the same, will it not, according to this view, whether zinc or zinc oxide be dissolved: in what will the difference consist? Is water formed when zinc oxide is acted upon by the spirit of salt? Experiment shows that a liquid is formed—can this be water? As the water will be in presence of the gas, it will be saturated with it—the gas must be got rid of from the liquid to obtain proof that water is formed.

Having ascertained that water is formed when zinc oxide is acted upon by spirit of salt, the production of water becomes a proof of the presence of oxygen—you are able now to test lime—again water is obtained. It is therefore established that lime is an oxide—probably the oxide of a metal like magnesium or zinc. Limestone stuff is therefore a distinct type of earthy substance, different from the earthy metallic oxides, formed by the association of a metallic oxide with a non-metallic oxide. You have yet to extend your experiments to the other metallic oxides to ascertain whether they all form compounds similar to limestone stuff.

If a course of experiments with the metals and metallic oxides (iron, copper, zinc, lead, magnesium, etc.) and acids (muriatic, nitric, sulphuric) were introduced here, there would be considerable opportunity of cultivating preparative skill.

Literary Work.

In carrying out such a course, attention must ever be paid to the literary side of the work. Rough but clear notes of the arguments used, of the things done and of the observations made must be jotted down, from time to time, *as each experiment proceeds*: on no account must this be done at any other time. A reasoned account of the work should then be written out at leisure, in flowing language, with due regard to style, never in the inexcusable form of a statement in advance of the conclusion to be arrived at ultimately, nor in the graceless hackneyed form of Experiment, Observation, Inference. It should never be forgotten that the prime object in view is to develop habits of logical thought and logical statement, together with the habit of inquiry. The clearest possible distinction must be drawn, therefore, between an experimental, reasoned inquiry into an undetermined issue and the practical demonstration or verification of a stated fact. It must be made clear that an experiment is an act performed with the definite object either of finding out something novel in the experience of the worker or of testing an assumption—that the mere demonstration or verification of the truth of a statement is not an experiment. The accounts should be fully illustrated by drawings and photographs.

In order to teach the use of books and develop the habit of purposed, serious reading, as wide a course as possible of reading should be associated with the experimental work. The books used should be mainly of general interest, and informative—books of reference, books of travel, &c.—though technical books may be consulted occasionally with advantage.

My scheme is now 'of age,' yet I see little reason to alter it; certainly not in principle and but little in detail. In practice, I should lay emphasis not only upon the chemical work—which, however, must always be of primary importance, as we live and have our being in chemical change—but also upon the physical, especially electricity. I should also develop the biological side so far as possible, in the later stages of the course. In fine, I should aim at making it complete as an elementary experimental course in geography! Still, it is useless to talk of what should be. Such work was difficult twenty-one years ago. To-day it can scarcely be attempted —didacticism and the worship of the knowledge idol reign supreme. The stranglehold of outside examinations is now mastering the schools, making rational teaching and the development of the spirit of inquiry all but impossible. True science is not being advanced in schools.

HENRY E. ARMSTRONG, *August* 1928.

APPENDIX III.

Entries and Successes of Pupils in Secondary Schools in the Examinations of the Eight Examining Bodies.

A.—*Extract from the Report of the Board of Education for the School Year,* 1925–26.

Table 1.

First School Certificate Examination.

Statement showing the number of candidates entering for the examination and the number obtaining a Certificate in the years 1919 to 1927.

Year.	Number of Candidates.	Number who obtained a Certificate.	Percentage.
1919 . . .	28,772	20,564	71·5
1920 . . .	31,645	20,770	65·6
1921 . . .	36,840	23,768	64·5
1922 . . .	43,116	28,899	67·0
1923 . . .	46,901	31,259	66·6
1924 . . .	49,343	31,738	64·3
1925 . . .	51,380	34,888	67·9
1926 . . .	53,564	34,277	64·0
1927 . . .	54,953	35,707	65·0

Table 2.

Second School Certificate Examination.

Statement showing the number of candidates entering for the examination and the number obtaining a Certificate in the years 1920 to 1927.

Year.	Number of Candidates.	Number who obtained a Certificate.	Percentage.
1920 . . .	3,183	2,224	69·9
1921 . . .	4,543	2,849	62·7
1922 . . .	5,375	3,442	64·0
1923 . . .	6,057	4,204	69·4
1924 . . .	6,590	4,406	66·9
1925 . . .	7,026	4,649	66·2
1926 . . .	7,778	5,132	65·9
1927 . . .	8,179	5,441	66·5

Table 3.

Second School Certificate Examination.

Statement showing the number of entries and the number of Certificates awarded in each of the groups in 1920 and in 1927.

Year.	Group.	No. of Entries. (*a*)	No. of Certs. awarded. (*b*)	Percentage of (*b*) to (*a*).	Percentage of (*a*) to total No. of Candidates.
1920	Classical Studies . . .	462	321	69·5	14·5
1927	,, ,, ...	844	547	64·8	10·3*
1920	Modern Studies . . .	1,266	969	76·5	39·8
1927	,, ,, ...	3,840	2,783	72·5	46·9*
1920	Mathematics . . .	498	287	57·6	45·7
	Science and Mathematics .	957	647	67·6	
1927	Mathematics . . .	551	286	51·9	41·6*
	Science and Mathematics .	2,853	1,759	61·7	

* The remaining 1·2 per cent. took the new group in the Examination held by London University, in which Geography is a Principal Subject.

TABLE 4.

FIRST SCHOOL CERTIFICATE EXAMINATION.

Statement showing the number of entries and the number of Passes in Individual Subjects in the years 1919, 1922, 1924 and 1926.

Subject.	1919			1922			1924			1926		
	No. of Entries.	Percentage of Entrants offering the Subject.	Per-centage of Passes with Credit.	No. of Entries.	Percentage of Entrants offering the Subject.	Per-centage of Passes with Credit.	No. of Entries.	Percentage of Entrants offering the Subject.	Per-centage of Passes with Credit.	No. of Entries.	Percentage of Entrants offering the Subject.	Per-centage of Passes with Credit.
English	28,479	99·0	71·4	42,969	99·5	61·5	50,176	100·0	61·5	54,360	100·0	62·1
History	25,539	88·8	57·0	37,911	87·8	48·1	45,797	92·8	49·2	48,084	89·8	44·5
Geography	24,486	85·1	52·3	32,107	74·4	48·5	35,285	71·5	43·0	37,043	69·2	42·0
Latin	10,102	35·1	48·7	15,705	36·4	40·8	19,768	40·1	44·8	22,127	41·3	43·9
French	25,762	89·5	58·3	40,069	92·8	56·2	48,233	97·8	48·9	52,231	97·5	49·7
Mathematics	26,438	91·9	65·7	39,180	90·8	51·3	46,604	94·5	48·7	50,956	95·1	47·7
Higher Mathematics	2,238	7·8	55·0	4,342	10·1	36·9	4,101	8·3	34·2	4,311	8·1	31·9
Botany	8,017	27·9	57·9	11,841	27·4	44·4	18,524	37·5	39·8	13,627	25·4	45·4
Chemistry	9,110	31·7	49·6	15,939	36·9	45·4	19,962	40·5	49·9	21,527	40·2	47·3
Physics	5,089	17·6	41·1	8,443	19·6	39·2	11,064	22·4	49·9	13,255	24·7	47·6
Elementary or Experimental Science	1,055	3·7	42·8	2,392	5·5	40·0	3,200	6·5	47·8	3,042	5·7	38·4
General Science	513	1·8	38·4	1,133	2·6	38·0	1,266	2·6	33·6	1,340	2·5	46·9
Applied Science	281	1·0	42·7	339	0·8	42·5	219	0·4	53·4	238	0·4	60·9
Mechanics	1,132	3·9	51·5	1,985	4·6	36·0	2,165	4·4	41·8	2,138	4·0	47·4
Heat, Light and Sound	1,218	4·2	53·5	2,351	5·4	54·2	2,687	5·4	50·4	2,980	5·6	47·0
Electricity and Magnetism	924	3·2	46·5	1,148	2·7	63·1	1,744	3·5	42·1	1,729	3·2	64·5
Biology	—	—	—	—	—	—	32	0·06	90·6	86	0·2	58·1
Agricultural Science	15	0·05	86·7	—	—	—	29	0·06	65·5	120	0·2	59·2
Music	204	0·7	72·1	520	1·2	67·7	665	1·4	63·0	607	1·1	55·4
Art	9,389	32·6	50·7	20,853	48·3	58·1	22,716	46·0	55·5	23,739	44·3	51·0

TABLE 5.

SECOND SCHOOL CERTIFICATE EXAMINATION.

Statement showing the number of entries and the number of Passes in Individual Subjects in the years 1920 and 1926.

Subject.	1920				1926			
	Number of Entries.	Percentage of Entrants offering the Subject.	Number obtaining a Pass.	Percentage obtaining a Pass.	Number of Entries.	Percentage of Entrants offering the Subject.	Number obtaining a Pass.	Percentage obtaining a Pass.
Latin	732	22·9	554	75·7	1,766	22·7	1,147	64·9
Greek	464	14·5	336	72·4	841	10·8	595	70·7
Ancient History	407	12·8	372	91·4	831	10·7	586	70·5
French	996	31·2	810	81·3	3,023	38·9	2,119	70·1
German	90	2·8	75	83·3	226	2·9	200	88·5
Italian	—	—	—	—	1	—	1	100·0
Russian	—	—	—	—	5	—	5	100·0
Spanish	1	—	1	100·0	52	0·7	48	92·4
Welsh	117	3·7	113	96·6	86	1·1	66	76·8
English	573	18·0	448	78·2	2,870	36·9	2,180	76·0
History	472	14·8	401	85·0	2,673	34·4	2,083	77·9
Mathematics	1,289	40·4	853	66·2	3,117	40·1	2,199	70·6
Physics	1,006	31·5	620	61·6	2,301	29·6	1,628	70·8
Chemistry	1,016	31·8	622	61·2	2,255	29·0	1,564	69·4
Physics with Chemistry	33	1·0	24	72·7	53	0·7	30	56·6
Botany	172	5·4	141	82·0	394	5·0	258	65·5
Zoology	23	0·7	20	87·0	140	1·8	96	68·6
Biology	3	—	3	100·0	56	0·7	36	64·3
Geography	100	3·1	91	91·0	378	4·9	263	69 6

B.—*Statement showing the Percentages of Passes and Credits in Science Subjects in the First School Certificate Examinations of the Eight Examining Bodies.*

I. University of Bristol.

Subject.	1922.		1924.		1926.	
	No. of Scripts.	Percentage of Passes with Credit.	No. of Scripts.	Percentage of Passes with Credit.	No. of Scripts.	Percentage of Passes with Credit.
Geography	299	48·49	280	31·4	270	34·8
Botany	92	56·56	104	62·5	128	78·1
Chemistry	189	39·20	212	64·6	247	31·9
Mathematics	382	50·0	401	67·0	416	43·9
Additional Mathematics	39	40·71	48	60·4	35	17·1
Mechanics	49	61·22	58	58·6	62	61·2
Physics	227	38·32	268	47·0	255	39·6
Elem. Agric. Science	—	—	9	100·0	17	85·6
Handicraft	20	83·0	6	66·6	3	66·6
Housecraft	20	45·0	7	57·1	25	52·0

II. University of Cambridge.

Local Examinations Syndicate.

Subject.	1922.		1924.		1926.	
	No. of Scripts.	Percentage of Passes with Credit.	No. of Scripts.	Percentage of Passes with Credit.	No. of Scripts.	Percentage of Passes with Credit.
Mathematics	5,898	60	6,228	48	6,205	53
Additional Mathematics I.	—	—	—	—	395	20
Additional Mathematics II.	—	—	—	—	124	44
Applied Mathematics	—	—	—	—	337	52
Chemistry	2,054	50	2,541	40	2,769	47
Physics	1,399	36	1,464	50	1,838	31
Botany	2,354	40	2,047	39	1,932	44
Natural History of Animals	43	67	52	71	45	49
Agricultural Science	83	61	83	65	63	52

Notes.

1. The questions in Additional Mathematics I were on Higher Algebra, Higher Geometry, and Trigonometry; in Additional Mathematics II on Analytical Geometry and Differential Calculus.

2. The percentage of candidates passing with credit in Physics in the Syndicate's School Certificate Examination is ordinarily from 40 to 45. The quality of the work appears to have been definitely worse than usual in this subject in July 1926. There was no raising of the standard.

III. University of Durham.

Year.	Subject.	No. of Scripts.	Percentage of Candidates passing with :		
			Dist.	Sp. Credit.	Credit.
1922	Mathematics (Elementary)	650	7·38	12·3	33·38
	Additional Mathematics.	38	—	—	18·42
	Mechanics . . .	10	—	10	60
	Exper. Science . .	102	1·96	11·76	40·19
	Chemistry . . .	167	4·19	10·77	43·71
	Physics . . .	163	3·06	8·58	36·19
	Botany . . .	117	1·7	10·25	45·29
1924	Mathematics . .	863	7·88	11·13	26·88
	Additional Mathematics.	16	12·50	25·00	18·75
	Mechanics . . .	26	11·54	19·23	38·46
	Exper. Science . .	68	—	13·24	47·06
	Chemistry . . .	309	4·21	11·97	29·77
	Physics . . .	257	6·23	14·01	36·96
	Botany . . .	218	3·21	15·14	49·54
	Biology . . .	14	—	7·14	71·43
	Geography . . .	821	2·31	8·65	39·10
	Geom. and Mechan. Drawing . . .	15	13·33	13·33	13·34
1926	Mathematics . .	1,093	6·04	9·06	32·58
	Additional Mathematics.	76	2·63	5·26	27·63
	Mechanics . . .	45	17·78	15·56	42·22
	Exper. Science . .	114	4·39	7·02	37·72
	Chemistry . . .	352	6·25	14·77	31·53
	Physics . . .	358	10·34	14·80	43·01
	Botany . . .	207	—	1·93	42·51
	Biology . . .	47	—	4·26	42·55
	Geography . . .	957	3·24	7·63	37·62
	Geom. and Mechan. Drawing . . .	12	8·33	8·33	16·67

IV. University of London.

Subject.	1922. Entered.	1922. Percentage passing with Credit.	1924. Entered.	1924. Percentage passing with Credit.	1926. Entered.	1926. Percentage passing with Credit.
Elem. Maths.	7,960	44·9	9,906	47·9	10,557	44·7
Advanced Maths.	785	23·8	804	20·0	599	38·7
Botany	2,320	49·4	2,950	45·8	2,970	45·6
Chemistry	4,408	40·5	5,371	53·7	5,732	40·8
General Physics	99	37·4	233	59·7	439	47·4
Gen. Elem. Science	209	61·7	200	42·0	206	59·7
Mechanics	908	40·1	1,109	44·6	1,337	47·2
Heat and Light and Sound	2,351	54·2	2,687	50·4	2,980	47·0
Electricity and Magnetism	1,148	63·1	1,744	42·1	1,729	64·5
General Biology	—	—	—	—	37	56·8
Domestic Science	87	40·2	88	5·7	113	55·8

V. Oxford University.

Delegacy of Local Examinations.

Subject.	1922 Entered.	1922 Percentage passing with Credit.	1924 Entered.	1924 Percentage passing with Credit.	1926 Entered.	1926 Percentage passing with Credit.
Mathematics	7,475	57·8	9,152	51·3	9·751	40·5
Additional Maths.	287	39·4	297	47·8	266	39·8
Botany	2,889	48·4	3,250	45·3	3,223	47·9
Exper. Science	97	48·5	—	—	—	—
Chemistry-with-Physics	—	—	81	19·7	156	46·7
Chemistry	1,843	51·2	2,953	46·3	2,658	48·1
General Science	732	39·1	813	43·3	741	57·4
Physics	2,087	48·6	2,958	47·7	3,212	50·4
Applied Science	339	42·5	219	50·4	238	60·9
Biology	—	—	—	—	26	92·3

VI. Oxford and Cambridge Joint Board.

—	1922		1924		1926	
	Total Entries	Percentage passing with credit	Total Entries	Percentage passing with credit	Total Entries	Percentage passing with credit
Maths. .	4,329	64·3	5,123	54·7	5,948	53·3
Higher Maths.	1,260	44·5	1,376	41·4	1,530	28·2
Botany .	320	22·5	324	13·9	362	14·1
Chem. .	798	42·6	1,038	45·3	1,151	47·6
Physics .	759	27·3	839	39·0	1,053	41·6
Ely. Science .	1,298	39·6	1,560	43·1	1,596	44·7
Gen. Science.	358	29·0	446	37·7	599	33·9
Biology .	—	—	—	—	10	60
Zoology .	—	—	22	77·3	20	75

VII. Joint Matriculation Board

of the Northern Universities of Manchester, Leeds, Sheffield, and Birmingham.

—	1922		1924		1926	
	No. of entries.	Percentage of Passes with Credit.	No. of entries.	Percentage of Passes with Credit.	No. of entries.	Percentage of Passes with Credit.
Total number of Candidates entered for the Exam. . . .	9,806	—	12,664	—	14,229	—
Subject.						
Mathematics . .	9,117	42·5	11,857	43·0	13,567	50·3
Mechanics . . .	250	25·2	335	29·6	254	48·8
Physics . . .	3,212	37·0	4,355	44·5	5,176	51·4
Chemistry . . .	4,773	48·4	6,227	55·2	6,661	53·6
Natural History . .	233	58·8	291	47·8	418	53·8
Botany . . .	2,735	36·9	3,547	34·2	3,788	42·2
Physics with Chemistry	327	25·2	858	26·9	1,176	27·6
Domestic Science .	82	53·5	125	52·0	31	48·4
Agricultural Science .	2	50·0	24	8·3	29	37·9

VIII. CENTRAL WELSH BOARD.

Subjects.	1922		1924		1926	
	No. of entries.	Percentage of Passes with Credit.	No. of entries.	Percentage of Passes with Credit.	No. of entries.	Percentage of Passes with Credit.
Mathematics	3,369	43·1	3,424	48·7	3,419	48·6
Mechanics	768	32·6	637	40·7	440	42·5
Physics	500	38·2	690	28·4	924	51
Chemistry	1,707	39·0	1,671	46·1	1,957	44·5
Geography	3,146	54·5	3,151	57·1	3,456	52·3
Botany	1,014	56·3	1,084	52·9	1,017	58·6
Biology	20	90·0	18	100	39	71·8
Geology	40	52·5	12	91·7	1	100
Agriculture	35	37·1	20	50	21	100
Metallurgy	13	76·9	46	47·8	13	53·8
Hygiene and Domestic Economy	—	—	—	—	—	—
Domestic Science with Hygiene	—	—	—	—	—	—
Domestic Science (including Elem. Hygiene and Physiology)	522	73·0	419	63·0	442	41·2
General Science	43	95·3	7	71·4	—	—

APPENDIX IV.

BOARD OF EDUCATION FINAL EXAMINATION OF STUDENTS IN TRAINING COLLEGES.

Two-Year Students.

Principles of Teaching.

Special course A: Detailed study and practice of methods of teaching *one* of the following subjects in schools offering advanced instruction to scholars over eleven. Intimate knowledge to be shown of subjects chosen, not only as part of our general education but also as it may be adapted for school purposes. The *examination paper deals mainly with the teaching of the special subject chosen.*

	1923	1924	1925	1926	1927
English, History, Welsh, Music, Drawing	268	208	172	147	134
Arith. and Maths.	41	67	32	38	29
Geography	54	54	64	57	61
Physics	26	33	24	25	17
Biology	23	12	4	13	16

Board of Education Final Examination of Students in Training Colleges.

1927 and (underlined) 1915.

Two-Year. Science.

	Number presented				Number who passed		
	Men	Women	Total	Per Cent.	Men	Women	Total
Board's Final Exam. as a whole .	832	3,403	4,235 3,392	—	706	3,143	3,849
Elementary Science	159 182	1,432 1,549	1,591 1,731	38 51	159	1,423	1,582
Gardening . .	67	124	191	4·5	65	121	186
Advanced Science, Physics . .	64 52	3 4	67 56	1·6 1·7	64	3	67
Advanced Science, Chemistry .	45 39	3 14	48 53	1·1 1·6	45	3	48
Advanced Science, Botany . .	6 12	59 267	65 279	1·5 8·2	6	58	64
Advanced Science, Biology . .	6	286	292	6·9	6	286	292
Advanced Science, Geology . .	—	—	—	—	—	—	—
Advanced Science, Zoology . .	—	20	20	·5	—	20	20
Advanced Science, Poultry, Husbandry . Rural Science .	3 36	— 41	3 77	— 2·3	3	—	3

SECTIONAL TRANSACTIONS.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 684.)

Thursday, September 6.

Prof. H. S. Allen.—*Progress in Band Spectra.*

The fluted spectrum known as a ' band spectrum ' is resolved under high dispersion into groups of fine lines in close sequence. The empirical relations found by Deslandres between the frequencies of the lines have received an explanation by applying the principles of Bohr's quantum theory of line spectra. It is now accepted that band spectra originate in molecules containing more than one atom. Such spectra may be classified as (1) pure rotation bands, the motion of the molecule being solely a rotation about an axis through the centre of mass; (2) vibration-rotation bands, this rotation being accompanied by a vibration of the nuclei along the line joining them; (3) electronic bands involving in addition to motions of rotation and vibration a change in the electronic configuration. The energy change in an electronic shift is so large that the spectrum may be in the visible or ultra-violet. The basic work in the application of Bohr's theory to such bands was done by Schwarzschild (1916) and Heurlinger (1918). It is assumed that the frequency of the radiation absorbed or emitted in a transition between two stationary states of the molecule is determined by Bohr's well-known frequency relation. The energy in a stationary state may conveniently be divided into (1) rotational energy E_m; (2) vibrational energy, E_n; (3) electronic energy, E_e.

Since 1926 considerable progress has been made in the interpretation of electronic shifts through the work of Birge, Hund, Mulliken and others. Hund has applied to band spectra the conception of electron spin which has proved fruitful in accounting for the multiple energy levels in atomic spectra. Birge and Mulliken have laid stress on the close similarity between the electronic levels of molecules and those of the ' corresponding ' atoms, *i.e.* atoms with the same number of outer electrons. Mulliken has extended the analogy by assigning inner quantum numbers to these levels, the values assumed being the same as Sommerfeld's values for corresponding atomic states.

The new methods are illustrated by the consideration of the band spectrum of water vapour which has been studied in the St. Andrews laboratory by D. Jack. Using Mulliken's notation he has given an interpretation of these bands, including the satellites and singlet series, and has obtained interesting results as to the selection rules.

The application of the new quantum mechanics has removed outstanding difficulties as regards quantum numbers in band spectra. Further progress in this direction is to be anticipated from the recent work of Dirac and of Darwin based on Schrödinger's wave mechanics.

Dr. Ezer Griffiths, F.R.S., and Mr. J. H. Awbery.—*The Measurement of Flame Temperatures.*

Two methods have been employed for the measurement of the temperature of a homogeneous flame.

In the one a refractory metal in the form of wire is heated electrically in vacuo, and the relation between temperature and heating current determined by an optical pyrometer. The same wire is then inserted in the flame, and the relation between temperature and heating current again determined. When the results are plotted graphically the point of intersection of the two lines will give the temperature of the flame, for at the temperature represented by this point the electrical supply is sufficient to balance the radiation loss, whether the wire is in vacuo or in the flame, so that the surrounding gas in the flame neither imparts nor abstracts heat from the wire.

Experiments have been made using wires of different diameters, and these have given identical values for the temperature of the flame investigated within the limits of experimental error.

In the second method a beam of light from an incandescent tungsten sphere was focussed through the flame on to the slit of a spectroscope. Sodium was introduced into the flame, and when the temperature of the flame was greater than that of the tungsten sphere, bright sodium lines showed up on a continuous spectrum background. If the temperature were lower, reversal of the sodium lines took place. By careful adjustment of the temperature of the tungsten sphere a point was reached when all trace of either bright or dark lines disappeared. This balance could be effected within a range of a few degrees. The corresponding temperature of the sphere was then determined by means of an optical pyrometer.

The first question studied was the influence of flame thickness, and it was found that the method gave results independent of the thickness of the flame. The second series of experiments was directed towards answering the question whether the temperature obtained in the spectrum-line reversal method was independent of the particular spectrum line employed. For this purpose the red lithium line and the yellow sodium lines were utilised. To obtain satisfactory reversals with the lithium line a thick flame from a water-cooled burner 10 inches in length was used. Separate experiments were made in which sodium and lithium salts were sprayed in the gas supply to the burner, and the red and yellow lines were also obtained simultaneously by using a solution of both salts in the spray. It was found that the temperatures obtained were the same whether the red or the yellow lines were employed as indicators. It may here be remarked that the lines used were principal lines of a spectral series, and the conclusion may be applicable to these lines alone.

The third series of observations was made on heterogeneous flames. Two flames at different temperatures were measured individually, and then superimposed and again measured. A mathematical investigation was also made of the problem and a formula deduced for the 'apparent' temperature of two superimposed flames from the individual values. A comparison of the observed and calculated data showed satisfactory agreement. It may be remarked that the value obtained for the 'apparent' temperature of two superimposed flames differs markedly from the mean of the two individual temperatures and is dependent on the relative positions of the flames. It would therefore appear that the method cannot be applied to estimate the average temperature of a heterogeneous flame.

A noteworthy feature of this method of measuring temperature is that it is devoid of 'time lag,' and so, for example, may prove of value in measuring temperatures in the explosion cycle of an internal combustion engine.

Some preliminary experiments have been carried out in conjunction with Mr. Fenning of the Engineering Department N.P.L., to test this application of the method, and gave quite promising results. The 'match' could be adjusted by successive trials in a series of five or six explosions.

Dr. J. Jackson.—*Free Pendulum Clocks.*

The clocks Shortt 3 and Shortt 11 were installed at the Royal Observatory, Greenwich, in November 1924 and May 1926 respectively. Each clock consists of a 'free pendulum' of invar swinging in a vacuum (1 inch of mercury) and a slave clock. The slave clock does all the work, including the release of the gravity lever which maintains the free pendulum. The only interference with the latter is for part of a second every 30 seconds. The slave is controlled by a mechanism brought into action when the impulse is ended, which takes place at a definite phase of the free pendulum.

The accuracy of such clocks greatly exceeds that of earlier types. The principal irregularities, shown by both clocks, is a temperature coefficient of 0·003 seconds per day per 1° F., and a gradual slowing down of the pendulum attributed to a growth of the invar rod. The growth for the 2-seconds pendulum is about 1 micron ($\frac{1}{1000}$ mm.) in 120 days, producing a decrease in the daily rate of ·037 seconds in 100 days. The growth of the invar of Shortt 3 appears to have been nearly constant since October 1925.

These clocks greatly improve the accuracy with which time signals can be sent, especially when cloudy weather prevents astronomical observation, but it appears that they are not sufficiently accurate to check small irregularities in the earth's rotation.

Discussion on *The Mechanism of Thunderstorms.* (Dr. G. C. Simpson, C.B., F.R.S.; Prof. C. T. R. Wilson, F.R.S.; Dr. R. A. Watson-Watt; Mr. B. T. G. Schonland; Prof. J. J. Nolan.)

Dr. G. C. Simpson, C.B., F.R.S.—The breaking-drop theory ascribes the origin of the electricity in a thunderstorm to the breaking of the raindrops, which are held up within the cloud by ascending currents having a vertical velocity of more than eight metres per second. The water after breaking has a positive charge, the corresponding negative charge going into the surrounding air. The positively charged water tends to accumulate in relatively small regions called the 'regions of separation,' while the negative electricity is distributed widely throughout the cloud by the air currents. The direct consequences of this theory are the following, the names in brackets giving the authors whose observations will be quoted to support the theory:

Rain.—Heavily charged rain from the centre of the storm is positively charged, while the lighter rain from the cloud as a whole is negatively charged (Simpson).

Form of lightning discharges.—Photographs of lightning show that the majority of lightning flashes start in positively charged clouds and generally from a definite small region of the cloud. Occasionally discharges take place from the ground to the negatively charged cloud; discharges of this nature are violent and branched upwards.

Discharges in tropical storms.—The region of separation is high in a tropical storm; hence the discharges which originate in the region of separation do not pass out of the cloud. The discharges which can be seen between the earth and the cloud are the relatively few discharges from ground to the negatively charged cloud (Watson Watt, Schonland).

Distribution of potential gradient in the neighbourhood of a thunderstorm.—As more positive than negative electricity is carried down by the rain, and as the accumulated positive charge in the region of separation is constantly being dissipated through lightning discharges, the cloud as a whole remains negatively charged. Thus the potential gradient is predominantly negative, and the current from the ground is mainly positive (Schonland, Wormell).

Polarity of Clouds.—A great deal has been written regarding the polarity of clouds, that is, whether the positive electricity in the cloud is above the negative or vice versa. Wilson and many others have concluded that a thundercloud has positive electricity in its upper parts and negative electricity in its lower parts. As this is the reverse of what one would expect on the breaking-drop theory it has been claimed that this disproves the breaking-drop theory. The observations on which these conclusions have been reached were measurements of the changes in field strength caused by lightning discharges. These observations, however, tell us nothing about the polarity of the cloud; and every observed field change can be as readily explained with a cloud of negative polarity as with one of positive polarity.

Conclusions.—The breaking-drop theory gives a physical explanation of the mechanism of a thunderstorm, which is quantitatively and qualitatively capable of explaining all observations so far made.

Friday, September 7.

Discussion on *The Photographic Measurement of Radiation.* (Dr. R. A. Sampson, F.R.S.; Dr. H. S. Spencer-Jones; Dr. F. C. Toy; Dr. I. O. Griffith; Dr. W. T. Astbury; Dr. R. A. Houstoun.)

Mr. H. F. Biggs.—*London's Theory of Valency and Stereochemistry.*

Mr. J. Thomson.—*Ultra-violet Radiations emitted by Point Discharges.*

Experiments are described in which electrical methods were employed to detect the radiations emitted by the gas in a spark discharge and to measure their intensities. The experiments show (*a*) the variation of the intensity of these radiations at a distance from their source when the pressure of the gas in the discharge tube is varied and the current in the spark is kept constant; (*b*) the variation of the intensity when the discharge current is varied and the pressure is maintained at a constant value.

The curves obtained depend upon both absorption and emission variations, and an attempt is made to estimate the relative importance of the two effects, and so to separate them. The evidence so far collected appears to indicate that the radiations are due to the impact of ions on neutral molecules.

Report of Committee on *Seismological Investigations.* (See p. 237.)

Monday, September 10.

Presidential Address by Prof. A. W. Porter, F.R.S., on *The Volta Effect: Old and New Evidence.* (See p. 21.)

Prof. P. Zeeman.—*The Spectrum of Ionised Argon and its Resolution in the Magnetic Field.*

Mr. R. A. Watson Watt.—*The Present State of our Knowledge of Atmospherics.*

This communication reviews, in a series of illustrative diagrams, the available evidence as to the origin and properties of naturally occurring electromagnetic waves of radiotelegraphic frequency.

The relative frequency of occurrence of atmospherics of different wave-forms, the mean peak field strengths and durations and the high frequency structure are examined. The number per unit time passing a selected threshold value is measured in temperate and tropical latitudes.

The mean directions of arrival of the predominant streams of atmospherics at various stations are studied with respect to their temporal variations, and the general distribution of sources of atmospherics is indicated by the intersections of these directions.

Specimens of the location of thunderstorms and frontal phenomena by radiotelegraphic direction finding on atmospherics are shown, together with distribution charts showing the places of origin of individual atmospherics on selected days.

Experiments for the determination of the effective disturbing range of atmospherics, in which aural reception of the atmospherics accompanying broadcast matter is combined with the direction-finding methods outlined, are discussed.

Finally some special features of the diurnal and seasonal variations in intensity of atmospheric disturbance in relation to solar and to terrestrial-magnetic influences are noted.

Mr. R. W. James.—*The Study of the Heat Vibrations of a Crystal Lattice by means of X-rays, and its Bearing on the Question of Zero Point Energy.*

From measurements of the intensity of reflexion of X-rays from a crystal face at a series of angles, it is possible, in some simple cases, to determine the average scattering power for X-rays of the atoms of which the crystal is composed, as a function of the angle of scattering, and hence to deduce the distribution of the electrons within the average atom. This distribution is affected by the heat vibrations of the crystal lattice, which must be taken into account in any comparison of the electron distribution, deduced in this way, with those given by different atomic models. Measurements over a wide range of temperatures have shown that, in the case of rock salt, the formula due originally to Debye and modified later by Waller, does represent the effect of the heat-motions on the intensity of reflexion. We are therefore justified in using a formula of this type to calculate from the observed scattering powers those corresponding to the atoms in a state of rest. If the atoms have energy of vibration at the absolute zero of temperature, a larger correction will be necessary than if they are at rest. The correction can be made for the two cases if we assume the zero point energy to be half a quantum per degree of freedom. Waller has shown how to calculate the scattering power of an atom, given the Schrödinger charge distribution for it, and Hartree has determined the approximate Schrödinger distributions for the ions Na^+ and Cl^-. The calculated scattering curves deduced from these results agree very

closely with those obtained from the experimental work, assuming zero-point energy, but deviate quite widely from those obtained without applying the correction for zero-point energy.

This appears to be a direct 'optical' confirmation of the existence of such energy. It is important to notice that the scattering power of an atom at large angles depends almost entirely on the inner electrons, the effect of the outer ones being destroyed by interference. The K electrons for an atom at rest are included within a domain whose radius is considerably smaller than the amplitude of vibration due to the zero-point energy. Thus the difference in the scattering curve for an atom at rest and for one vibrating with this amplitude is considerable.

Mr. David F. Martyn.—*Frequency Variations of the Triode Oscillator.*

Previous theories of frequency variation are inadequate to account for the large variations which can be obtained. A theory based on the flow of grid current is outlined and shown to be capable of explaining all the observed variations in detail. The conditions for the elimination of grid current are described, and it is shown that when no grid current flows the frequency of the oscillator can be kept constant to one part in 100,000 without special precautions, thus greatly increasing the value of the triode oscillator as a means of making physical measurements of high accuracy.

Afternoon.

Prof. E. Taylor Jones.—Lecture, with Demonstration, on *Spark Ignition.*

Department of Cosmical Physics.

Mr. A. H. R. Goldie.—*Magnetic Storms: the disturbing Electrical Fields as deduced from the records of the Magnetographs at Lerwick and Eskdalemuir Observatories.*

The material used consists of magnetic records from the Meteorological Office Observatories at Lerwick (Shetlands) and Eskdalemuir (Dumfriesshire), and in certain cases also from Abinger (Surrey).

Attention is first called to certain features of magnetic disturbance and of the diurnal variation of magnetic force on disturbed days at the two Scottish observatories, in relation to the corresponding changes at more southerly observatories. An attempt is then made to compute the position and strength, hour by hour, of the electric current system capable of producing the magnetic displacements recorded at the observatories during certain magnetic storms of the year 1926. The features common to most of the storms are found to be that during the afternoon and early evening period, and again for some hours after midnight, the electric current system has at least approximately a linear resultant running roughly W.S.W. to E.N.E. The current in the later of these two periods is oppositely directed to that in the earlier period, but the strength and altitude are of the same order. In the later period also, in all cases examined, the current position is farther north than in the earlier period, so that, though in many cases the initial current lies between Lerwick and Eskdalemuir, no cases have yet been found where the final current is not to northward of Lerwick.

Mr. M. A. Giblett.—*Wind Structure Research at the Royal Airship Works, Cardington.*

The paper describes the experiments which are in progress at the Meteorological Office, Royal Airship Works, Cardington, Beds, to determine the detailed structure of the wind and the variations of the wind over short distances and in short intervals of time. Four anemographs with specially open time scales and an electrically controlled time-marking system are in use, the group of instruments being contained in an equilateral triangle of side 700 ft.

The various types of records obtained will be shown, together with some preliminary results.

An exhibit of records, &c., will be on view throughout the meeting as part of the Meteorological Exhibition in the Randolph Hall.

Mr. T. L. MacDonald.—*The Probable Errors of Eye Estimations of Planetary Detail.*

Tuesday, September 11.

Discussion on *The Scattering of Electrons by Crystals.* (Dr. C. J. Davisson; Prof. G. P. Thomson; Dr. L. de Broglie.)

Dr. C. J. Davisson.—Experiments reveal that the interaction between a homogeneous beam of electrons and a crystal of nickel is similar to the interaction between the same crystal and a beam of monochromatic X-rays; the electron beam is regularly but selectively reflected from the face of the crystal (analogue of the Bragg X-ray reflection phenomenon), and at critical speeds of bombardment beams of electrons issue from the incidence side of the crystal in other directions as well (analogue of the Laue X-ray diffraction phenomenon). Unlike the Laue beams, however, the electron beams do not proceed from the crystal in the direction of regular reflection from its principal sets of Bragg atom planes. That this simple geometrical relation obtains in the case of X-ray diffraction is due to the fact that for X-rays the indices of refraction of materials are equal sensibly to unity. It is due to this circumstance also that the wave-lengths of Laue beams can be calculated by means of the Bragg formula. If the refractive index were not unity the wave-lengths of Laue beams issuing from the incidence side of the crystal could still be calculated, for, regardless of the value of the index, the wave-length of each such beam satisfies the plane grating formula $n\lambda = D(\sin\theta_1 - \sin\theta_2)$ with respect to one or another of the atomic plane gratings to which the surface layer of atoms is equivalent. This formula has been used to calculate equivalent wave-lengths of electron beams of various speeds, and in all cases the values so found are in acceptable agreement with the values calculated from the de Broglie formula $\lambda = h/mv$. The same procedure cannot be used to calculate equivalent wave-lengths of the beam regularly reflected from the crystal face, for as a plane grating beam it is of zero order and its wave-length is therefore indeterminate. The observations on this beam are particularly suitable, however, for calculating indices of refraction of the crystal for electrons of various speeds or wave-lengths. These calculations and others based on the data of the diffraction beams lead to a definite dispersion curve for nickel. For bombarding potentials V greater than 100 volts the index μ is given by $\mu = (1 + \Phi/V)^{\frac{1}{2}}$ where Φ is a constant, equal approximately to 18 volts. In terms of the wave theory of mechanics this means that the average potential inside the crystal is less by 18 volts than that outside. Below 100 volts the dispersion curve is complicated and exhibits features suggestive of optical anomalous dispersion.

Prof. G. P. Thomson.—The passage of cathode rays through thin films of metals or celluloid results in a diffraction of the de Broglie waves associated with the electrons. This gives rise to a pattern similar to that formed by X-rays under the same conditions, and the whole of the pattern can be predicted with an accuracy of about 1 per cent. from the known crystal structure of the solid and de Broglie's expression for the wave-length. This has been proved by workers at Aberdeen University for celluloid, aluminium, gold, platinum, silver, copper and tin. The electrons which form the pattern have apparently the same speed as the original cathode rays.

Rupp in Germany has extended these results to the cases of slow electrons of about 300 volts, and finds a small discrepancy which he ascribes to a refraction of the electron waves.

A point of great theoretical interest is the length of the train of waves associated with an electron, and the question of the relation to each other of the waves associated with the different electrons in a beam of cathode rays. The Aberdeen experiments appear to show that each electron has a coherent train of at least fifty waves associated with it. This number probably depends on the conditions of experiment. In the case of the β rays from RaE the train is probably a very short one.

Prof. W. J. de Haas.—*Some New Experiments on Supraconductors.*

The theories on electric conductivity may be divided into two groups. The one treats the metal as containing a gas of electrons—degenerated or not. According to the theories of the other group, the electrons are passing from one atom to the other.

The writer thinks that the last point of view is the right one. It is possible to demonstrate that in graphite placed in a magnetic field nothing can be detected of a Lorentz force on the electrons. Other investigations on bismuth contradict the results obtained with graphite. The experiments are not yet conclusive.

However, Kamerlingh Onnes made a very interesting experiment with a supraconductor. A wire of copper covered with a very thin sheet of tin and placed in a cryostate at the temperature of liquid helium shows supraconductivity at the ordinary threshold value of the temperature. Hence the electrons do not pass from the tin to the copper. There is no internal friction, as in a gas.

There are still new phenomena difficult to understand under the assumption of a gas of electrons.

It is a known fact that when a supraconductor is cooled down to the temperature of liquid helium a magnetic field may restore the ordinary qualities of conduction in the metal. Later experiments show that this phenomenon is a real hysteresis phenomenon. The resistance of the metal does not return at the same value of the field at which it vanishes. Now a phenomenon of hysteresis is something of a memory of matter. And all things occurring in time must statistically occur also in the volume of the metal. It is necessary that quite a lot of electrons be involved in the process of hysteresis. It seems possible that the hysteresis is made by a row of electrons passing rows of atoms.

Why do the electrons pass in rows in a supraconductor ? I think the phenomenon of supraconductivity has something to do with the zero-point energy. Nature gives in a supraconductor an example of a hidden and profound synchronism only possible with very regularly built atoms.

Dr. L. F. Richardson, F.R.S.—*The Deferred Approach to the Limit.*

In the Infinitesimal Calculus the passage to the limit comes early, namely in the definition of a derivative or integral, and the solution of special problems follows later. As a typical special problem let us consider a differential equation holding throughout a range of the independent variable together with boundary conditions at one or both ends of the range.

When considerable difficulties have been encountered in special problems treated by this ' previous passage to the limit,' it has been customary instead to pass towards the limit concurrently with the solving of the special problem, by employing finite differences of suitably high order, in the manner described in books on Interpolation. In this ' concurrent approach to the limit ' the difference-equations are always of higher order than the differential-equation which they replace.

The object of the present note is to call attention to a third process in which the passage towards the limit is deferred until after the special problem has been replaced by a difference-problem of the same order (except for the first step of some solutions) and solved for two or more sizes of the difference of the independent variable. The advantage of the ' deferred ' in comparison with the ' concurrent ' method lies in the lower order of the difference-equation. The advantage becomes important when the given problem becomes complicated. The ' deferred approach ' is an easy routine which should attract those who want numerical solutions of problems that are numerically definite. It may be performed by plotting the numerical results, obtained separately for several different sizes of differences of the independent variable, against the squares of those sizes. Ordinarily the plotted points are nearly on a straight line which cuts one axis close to the desired limit.

At the Meeting illustrations were given, one of which, concerning a fourfold integral was about to appear in the *Philosophical Magazine*, under a title beginning ' The Amount of uniformly diffused Light . . . .'

An extended discussion is to be found in *Phil. Trans. A.*, vol. ccxxvi, pp. 299–361, by L. F. Richardson and J. Arthur Gaunt. It is sometimes possible to retain a variable parameter throughout, as H. Jeffreys has shown (*Phil. Mag.*, October 1926).

Dr. G. Green.—*The Condenser Telephone.*

Prof. J. G. Gray.—*Four new Gyroscopic Tops.*

Dr. A. Ferguson and Mr. J. A. Hakes.—*The Simultaneous Determination of Surface Tension and Density.*

If a capillary tube of radius r is immersed vertically to a depth h in a liquid of density ρ and surface tension γ, the value of γ may be deduced from observation of

the pressure ($g\rho_1 h_1$) required to force the meniscus in the capillary down to the lower end of the immersed tube. The working formula may be written as

$$h_1 = \frac{\rho}{\rho_1}\left(h - \frac{r}{3}\right) + \frac{A}{\rho_1},$$

where A stands for $\frac{2\gamma}{gr}$.

Hence if the tube is immersed to a depth equal to one-third of the radius, γ may be deduced independently of any knowledge of the density of the liquid under test. More generally, if observations of different values of h_1 and h are made, a plot of h_1 against $\left(h - \frac{r}{3}\right)$ yields a linear graph from the slope and intercept of which accurate value of both γ and ρ may be determined.

Similar considerations apply to the method described some time ago (*Proc. Phys. Soc.* 36, 37, 1923) for the measurement of γ for a liquid obtainable only in small quantities of the order of a few cubic millimetres. A column of liquid of length h is contained in a vertical capillary, and the pressure ($g\rho_1 h_1$) is measured which is required to force the column down the tube until the lower meniscus is plane at the lower end of the capillary. We then have

$$h_1 = -\frac{\rho}{\rho_1}\left(h + \frac{r}{3}\right) + \frac{A}{\rho_1},$$

and we can similarly obtain a rectilinear plot giving values of γ and ρ for a liquid obtainable in small quantity only.

Department of Cosmical Physics.

Dr. F. J. W. Whipple.—*The Propagation of Air Waves to great Distances in relation to the Constitution of the Upper Atmosphere.*

The sound of a great explosion can usually be heard at distances exceeding 200 kilometres. The source of sound is surrounded by an inner zone of audibility, and beyond a zone of silence there is an outer zone of audibility. Generally the outer zone does not completely surround the source.

To investigate the phenomenon explosions have been produced at known times and apparatus sensitive to inaudible air-waves has been developed. From a knowledge of the times taken to reach different distances in the outer zone, or zone of abnormal audibility, the velocity of the air-waves at various heights can be deduced. The observations indicate that the heights reached by the waves are usually between 40 km. and 50 km., and that the velocity of sound at such heights is greater than near the ground. Thus the observations support the theory of Lindemann and Dobson, according to which there is warm air above the stratosphere.

It is hoped that further observations will make it possible to follow the changes in the condition of this warm part of the atmosphere. Hitherto the investigation has been carried on most vigorously in Germany, but systematic observations have been made in England during 1927 and 1928, the origin of the air-waves being a 16-in. gun in the Isle of Grain. The most successful receiving stations are at Birmingham and Bristol at ranges of 213 km. and 230 km. respectively. Hot-wire microphones are used.

The time of passage of the air-waves to Birmingham has varied between 11 mins. 48 secs. and 12 mins. 18 secs. For Bristol the departures from the average time 12 mins. 53 secs. have been small. Observations giving the angle of descent of the air-waves have been made at these two stations recently. It is found that the waves reaching Birmingham have the flatter trajectories. The interpretation of observations from a couple of stations is uncertain owing to the impossibility of allowing for wind. If this factor be ignored the observations at Bristol and Birmingham on May 11, 1928, indicate that the uniform temperature of the stratosphere extended to 30 km. above ground, and that the temperatures at 40 km. and 50 km. were about 15° C. and 70° C. respectively.

Mr. G. A. Clarke.—*The Association of Cloud with Weather.*

SECTION B.—CHEMISTRY.

Thursday, September 6.

Presidential Address by Prof. E. C. C. Baly, C.B.E., F.R.S., on *Fluorescence, Phosphorescence, and Chemical Reaction* (see p. 35). (Followed by Discussion.)

Exhibition of 'Kinacolour' Process by Messrs. Kodak, Ltd.

Friday, September 7.

Discussion on *Fermentation.* (Dr. J. Vargas Eyre; Dr. A. C. Thaysen; Prof. J. C. Drummond; Mr. Julian L. Baker; Mr. H. F. E. Hulton.)

A discussion devoted chiefly to the chemical and physico-chemical aspects of fermentative processes.

Exhibition of Cinematograph Films.

(Repeated on Monday and Tuesday, September 10, 11.)

The following films are expected to be shown :—

(*a*) The Story of Beautiful Colours.
(*b*) Buxton Quarry Blast.
(*c*) Slow-motion Picture of a Big Blast.
(*d*) Sulphur Mining.
(The above kindly lent by Imperial Chemical Industries, Ltd.)
(*e*) Iron Ore to Pig Iron.
(*f*) Pig Iron to Steel.
(*g*) A Trip through Film-land.
(*h*) The Making of a Fine Chemical.
(The above kindly lent by Messrs. Kodak, Ltd.)
(*i*) The Combination of Molecules.
(Kindly lent by Sir James Irvine, F.R.S.)

Afternoon.

Visits to Works of (*a*) Messrs. R. & W. Watson, Ltd., Paper-makers, Linwood; (*b*) Messrs. J. & R. Tennent, Ltd., Wellpark Brewery, Duke Street.

Visit to Royal Technical College, George Street.

Saturday, September 8.

Visit to Ardeer Factory of Nobel's Explosives Co., on invitation of Messrs. Imperial Chemical Industries, Ltd.

Monday, September 10.

Dr. E. K. Rideal, assisted by Mr. F. E. Smith.—*Demonstrations of Light Reactions.* (Followed by Discussion.)

Light is emitted in a variety of chemical and physico-chemical processes. Until recently these chemiluminescent reactions have been regarded in the light of interesting

curiosities rather than as important processes which may afford some insight into the mechanism of the transfer of energy between molecules. Amongst those reactions which exhibit the phenomenon of light emission to a marked extent and which can be demonstrated are :—

(1) *Excitation of Light Emission by Physical Processes.*

(*a*) The crystallisation of arsenious oxide from supersaturated solutions.
(*b*) The emission of light after light absorption by 'phosphors.'
(*c*) The emission of light after electron collision by 'phosphors.'

(2) *Light Emission in Gaseous Reactions.*

(*a*) The oxidation of phosphorus vapour and its inhibition by vapours of organic compounds.
(*b*) The cold autoxidation of ether vapour.
(*c*) The interaction of chlorine and acetylene.
(*d*) The interaction of chlorine and ammonia.
(*e*) The decay of active nitrogen.
(*f*) The gaseous and surface catalysed interaction of the vapours of potassium and mercuric chloride.

(3) *Light Emission in Solution.*

(*a*) The oxidation of phosphorus in acetic acid by hydrogen peroxide.
(*b*) The interaction of pyrogallol-formaldehyde mixtures and hydrogen peroxide.
(*c*) The interaction of phenylmagnesium iodide and chlorpicrin.
(*d*) The oxidation of siloxene.

Prof. J. C. Drummond.—*The Luciferin-Luciferase System.*

Exhibition of Cinematograph Films (as on Friday, September 7).

Afternoon.

Visit to Corporation Gas Works, Maclaurin Plant, Dalmarnock, Provan Gas Works, and Provan Chemical Works.

Visit to Royal Technical College, George Street.

Tuesday, September 11.

Discussion on *Recent Advances in Stereo-chemistry.* (Sir William Pope, F.R.S., Dr. H. J. Backer, Prof. C. S. Gibson, Prof. J. Kenner, F.R.S., Dr. N. V. Sidgwick, F.R.S., Prof. G. T. Morgan, F.R.S., Dr. J. Kenyon.)

Exhibition of Cinematograph Films (as on Friday, September 7).

Afternoon.

Visit to Works of Messrs. Shanks & Co., Ltd.

SECTION C.—GEOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 684.)

Thursday, September 6.

The Geology of the Glasgow District.

(*a*) Prof. J. W. Gregory, F.R.S.—*General Geology.*
(*b*) Dr. G. W. Tyrrell.—*Igneous Rocks.*
(*c*) Dr. J. Weir.—*Palæontology.*

Mr. R. M. Craig.—*On the Occurrence of Flinty Crush-rock in the Outer Hebrides.*

The Outer Hebrides, so far as they have been examined, appear to consist mainly of a complex of gneissic rocks similar in most respects to those already described from the western seaboard of Sutherland and Ross. They are mainly orthogneisses of various types, but paragneisses also occur, including crystalline limestones, quartz schists and graphite schists. Later are dykes of quartz dolerite, tholeiite, olivine dolerite (often of Crinan type) and camptonite, most of which are probably of Tertiary age.

Probably the chief feature of interest in these islands is the great zone of shearing, due to earth movement from E.–W. or S.E.–N.W., which traverses the E. coast in a generally N.–S. direction. The shearing is accompanied by extensive crushing of the rocks of the gneissic complex leading to the production of mylonites on an extensive scale. A further stage in dynamic action is shown in the production from the finely ground material of flinty crush-rocks. In places these show signs of fusion, forming pseudo-tachylyte, which behaves intrusively to the surrounding rocks. Exceptionally the fused material (pseudo-tachylyte) exhibits signs of recrystallisation in the presence of spherulites and in groups of microlites of felspar and hornblende.

Mr. Gerald Andrew.—(*a*) *Note on a Basic Sill in North-west Donegal.* (*b*) *The Contact Relations of the Donegal Granite.*

(*a*)

A member of the early basic sill intrusions into rocks of Dalradian type in N.W. Donegal is exceptionally fresh. The rock is an ophitic quartz-dolerite, with faintly brownish augite, oligoclase-labradorite, and interstitial micrographic quartz-felspar intergrowths; accessories are opaque ore (ilmenite), apatite, biotite and hornblende. The last two occur apparently independently, as well as in association with other minerals, the biotite fringing and partly intergrown with ilmenite, and the hornblende occasionally fringing the augite. The hornblende is pleochroic, brownish green to green, and is not uralitic in character or origin.

The locality of the best example is on the south-east shore of Marble Hill Strand (1 in. Sheet 4), S.E. of Dunfanaghy. Similar dolerite occurs on the western base of Errigal (1 in. Sheet 9), N. of Dunlewy. On the promontory of Rosguill (Sheet 4) sills have fresh augite cores, the felspar being decomposed, but the original structure of the rock is retained.

The sills are cut by acid minor intrusions (connected with the granite) in Rosguill and at Marble Hill Strand, and are members of the group which has elsewhere suffered shearing with the schists. They are therefore earlier than the main movement, which was pre-Caledonian (*cf.* Fearnsides and others, *Proc. R.I.A.* 26, p. 100).

The lowest grade members of this group known hitherto occur on the W. Coast of Scotland (*Mem. Surv. Scot.* Sh. 36, pp. 50, 52; Sh. 37, p. 65, &c.).

(*b*)

I. Characters of the N.W. Part of the Main Granite Area.

The granite is a pink granodiorite, in parts strongly foliated parallel with the margin, and with the foliation of the country rock. Large xenoliths are common, with their foliation parallel with that of the granite in most cases, but at an angle with it in some (*Mem. Geol. Surv. Ireland*, Sheets 3, 4, 5, &c., p. 71). The country is intruded lit-par-lit at the margin. Xenoliths of biotite-schist, one of the commonest rocks outside the granite, are rare, unless certain biotite-rich grey gneissose rocks, previously described (*Mem. cit.*, p. 134) as crushed granite, are such xenoliths. Xenoliths of quartzite, limestone, flagstone and amphibolite show no signs of assimilation, except in the case of the pegmatites intersecting limestones, and certain amphibolite xenoliths, the field relations of which are obscure.

II. Characters of the Rosguill Granite Area.

The foliation of this mass is weak, xenoliths are exceptionally common, and swarms of small (2–6 in.) xenoliths occur (polygenetic agmatite). There is no marginal foliated biotite-gneiss, the country being mainly pelitic hornfels poor in biotite (andalusite or sillimanite hornfels). In the case of at least one amphibolite

xenolith, which is particularly clearly exposed, local assimilation has taken place. The centre of the xenolith is pierced by granitic veins 1–3 in. thick. These become closer near the margin, and the critical stage is that of an agmatite, in which biotite is produced at the expense of the hornblende of the amphibolite, and the orthoclase of the granite, which is absent from the veins (*cf.* Harker, 'Tert. Ig. Rocks Skye,' p. 171). The felspar of the xenolith is a strongly zoned (Andesine-Oligoclase) plagioclase. The clots appear to be disseminated through the granite as biotite-rich patches smaller in size the further into the granite they occur. The granite is white where xenolithic, but is otherwise pinkish. The zone of mixing is approximately 4–6 yards along the strike of the xenolith, and less transversely.

III. Conclusions.

The granite was intruded later than the tectonic maximum. The foliation of the biotite-rich rocks is not attributable to crushing of the granite, and is considered to be a relict structure. The rocks themselves are either simple or injected xenoliths of biotite-schist. They occur where xenoliths of schist are to be expected, from the nature of the country rock. Nearest the margin of the granite they occasionally carry pink porphyroblasts of oligoclase. Farther within the granite a banded gneiss (1–3 in. bands), with alternating grey biotite-rich bands and pink granitic bands, occurs. In the grey portion small grains of pink felspar are common, and a slice showed a small clot of spinel and corundum, with epidote. The grey portion is considered to be the last recognisable stage of the biotite-schist in the processes of incorporation.

It is considered that the evidence establishes that (1) under the low-grade conditions obtaining in N.W. Donegal certain rocks are refractory, *e.g.* quartzite, limestone, flag, aluminous shale, amphibolite; (2) certain biotite-schists, of mineralogical composition similar to that of the granite, tend to be assimilated, and other rocks (*e.g.* amphibolite) follow suit if able to form a mineral aggregate similar to that of the invading rock. The former process depends on mechanical (lit-par-lit) incorporation mainly, and on the use of the granite juices (water, &c.) for injection; the latter on chemical reaction with the fluid part of the magma. Lit-par-lit injection on a fine scale is especially favoured by the existence of previous strong schistose or bedded structure in micaceous (or chloritic) schists or slates. Under the contact effect of the granite the mica tends to grow, but in one plane, and thus emphasises the fissility. In other rocks (*e.g.* quartzite, &c.) a granular aggregate is produced by the production of equidimensional crystals (hornfels structure) in the main mass of the rock, with consequent welding of the planes of fissility, and 'lit' structure is coarse, or does not occur.

The phenomena are similar to those described by Cole in S.W. Donegal (*Proc. R.I.A.* 24 B, pp. 203–230; *Proc. R.I.A.* 25 B., pp. 117–123; *Proc. R.I.A.* 24 B, pp. 361–370), and the above account may be considered as supplementary to these.

Mr. J. E. Richey.—*Ring-dykes of Slieve Gullion, Ireland.*

The Slieve Gullion Tertiary Igneous Complex is intruded around the south-west end of the Devonian granite of Newry and mainly consists of: (1) a ring-complex of vents and two acid ring-dykes, seven miles in diameter, that mark the course of a ring-fissure;[1] and (2) a north-westerly extending belt of basic and acid intrusions bisecting the area enclosed by the ring-complex. Basic minor intrusions include N.W. dykes and centrally-inclined sheets. The area was mapped and described by Nolan, Egan and Traill during the primary survey of Ireland fifty years ago.[2] The writer's preliminary reinvestigation has been more especially concerned with the age-relations of the larger rock-masses mapped, determined in the case of intrusions mainly by chilled margins.

The time-scale now established for the ring-complex is as follows: (1) Basalt (Forkhill district), non-porphyritic olivine-rich and non-porphyritic and porphyritic olivine-poor, in small masses, associated with and yielding fragments to the vent-

[1] Recognised by W. B. Wright in 'Tertiary and Post-Tertiary Geology of Mull, &c.' (*Mem. Geol. Surv.*), 1924, p. 7.

[2] Geological Survey of Ireland, one-inch map, Sheets 59, 60, 70 and 71, and Explanatory Memoirs (1875–78). See also J. Nolan, *Journ. Roy. Geol. Soc. Ireland*, vol. iv, 1877, p. 233, and *Geol. Mag.*, Dec. ii, vol. v, 1878, p. 445; and Sir A. Geikie, 'Ancient Volcanoes,' vol. ii, 1897, p. 422.

agglomerates. Non-porphyritic varieties are locally slaggy and are considered to be Tertiary plateau lavas let down within the vents and so preserved; (2) finely brecciated country rock bordering the ring-fissure to north and east, considered due in part to explosion, in part to fault-movement along the ring-fissure; (3) porphyritic hornblende-granophyre ring-dyke along three-quarters of the ring-fissure in contact with (2), brecciated next to (4); (4) agglomerates and explosion breccias in vents along S.W. part of ring-fissure (Forkhill district), chiefly of fragments of country rocks, but including also trachytic rocks that presumably originated from the vents; (5) porphyritic felsite ring-dyke, accompanying and intruding (4).

The earlier ring-dyke (3) where best seen in section (Cam Lough) is inclined northwards, *i.e.* outwards, at about 70 degrees. There is no evidence of any marked subsidence of the area enclosed by the ring-complex. The ring-dykes follow a ring-fissure that has been enlarged, locally at any rate, by volcanic action.

The N.W. belt consists of intrusions of biotite-gabbro (Slieve Gullion), quartz-gabbro (Foughill; E. of Flurrybridge), and non-porphyritic or sparsely porphyritic granophyres (Slieve Gullion, Foughill, Anglesey Mountain). Structural and time relations have not yet been fully worked out. Granophyres, however, are well seen to N.W. and S.E. in intrusive contact with the porphyritic granophyre ring-dyke, and are clearly later in age.

It would seem that the ring-complex marks the first intrusive phase, and that subsequently igneous activity became localised along a N.W. line of weakness.

Mr. T. M. Finlay.—*Rolled Spherulites in Felsite from the Shetlands.*

These abnormal structures occur in a series of dyke rocks cutting both the Ronas Hill granite mass of the north-west of Shetland and the gneiss into which the granite is intruded. The first specimens noted occurred as scree material, and the features displayed on the weathered surfaces suggested the preservation of an organically-formed rock by hornfelsing, so strongly did they simulate organic structures. Later, however, a series of dykes, varying in width from 50 ft. down to 18 in., was found *in situ*, placing the intrusive, igneous origin of the rock beyond doubt.

The rock is generally blue in colour, is extremely hard, and often splits readily into slabs of varying thickness. Incidentally these qualities of hardness and fissility made the rock a suitable one for implement-making; polished flensing knives made from it are peculiar to the districts of Northmaven and North Roe, where the dykes occur.

Microscopic examination of the normal type of rock in all the dykes shows that the dominant structure developed is the spherulite. These structures are composed of delicate radiating needles of Riebeckite forming beautiful spherulites up to $\frac{1}{2}$ in. in diameter, embedded in what is now partly quartz, partly a micropegmatitic intergrowth of quartz and felspar on an exceedingly minute scale. Where this normal type of consolidation is departed from abnormal structures abound. These take the form of (*a*) broken spherulites, the riebeckite needles being spread out along lines of flow; (*b*) rolled spherulites, where a spherulitic or glassy spheroidal nucleus has been rolled over and over in a layer of viscous magma giving rise to spiral structures as seen on a fractured surface; (*c*) enlarged spherulites where a similar nucleus is bordered by radiating tubules filled with quartz and micropegmatite ('solid vesicles'), the whole bounded by a distinct glassy wall; and finally (*d*) areas, laminar, finger-like or irregular in outline with a remarkable pseudo-cellular internal structure resulting from the arrangement of the riebeckite microlites; the outer surfaces of these patches are also studded with a system of tubules ('solid vesicles') often septate and bent in the direction of flow.

Analysis shows the rock to be highly acid (SiO_2 76%), rich in alkalies, magnesia absent, and lime nearly so. While no attempt is made at present to arrive at the origin of these structures, it is suggested that they are paralleled by the lithophysal and spherulitic structures so often noted in rhyolites, and that the same factors are operative in their formation.

A similar rock is known from Northern Nigeria, also a dyke rock and associated with granite; in the specimen examined only the spherulitic type of crystallisation was developed.

AFTERNOON.

Excursion to Bishopbriggs and Torrance. (Leader: Prof. J. W. Gregory, F.R.S.)

Friday, September 7.

Mr. M. Macgregor.—*The Pre-glacial Valley of the Clyde and its Tributaries.*

The present drainage system of the Clyde is superimposed upon a much older system filled in and concealed by glacial and post-glacial deposits. These buried valleys are deeper, and as a rule more open and less gorge-like, than the present ravines. The most remarkable feature in connection with them is the relation of the great Kelvin or Bearsden channel to that of the Clyde. Rockhead was found in the former at a depth of 240 feet below O.D. (boring near Drumry), while the greatest depth of superficial material recorded below O.D. in the case of the pre-glacial Clyde is only about 100 feet (near Glasgow Bridge) and in the case of the old valley of the Black Cart 115 feet (between Paisley and Renfrew). This superdeepening of the Kelvin has been ascribed to glacial erosion, but it may be suggested that in the pre-glacial Clyde-Kelvin channels we are dealing with two entirely different drainage systems. The pre-glacial topography of the Glasgow district must have sculptured at a time when the land stood at least 300 feet higher than it does at present, and the drainage system seems to have developed as follows :—

(1) The Kelvin-Lower Clyde an obsequent stream ; the Kelvin hollow eroded towards a base-level at least 300 feet higher than present-day base-level.

(2) Submergence of the land by about 100 feet accompanied by silting-up.

(3) Renewed erosion towards a new base-level. To this period may be referred the development of the Upper Clyde as the important obsequent stream. The earlier Kelvin-Lower Clyde may have had many of its head-waters diverted, while the Upper Clyde was cutting backwards and extending its drainage area. The Clyde and its tributaries (Black Cart, &c.) were eroding rock-gorges, while the Kelvin was merely a sluggish stream ' winding over alluvial flats and cutting here and there into the valley sides ' (Glasgow District Memoir, p. 219).

The alluvial materials with which the pre-glacial Clyde valleys are mainly filled seem to be of late glacial age since they rest frequently on boulder-clay. But in the case of the deep Kelvin channel the lowest beds may be taken to represent the relatively undisturbed detrital material of pre-glacial times.

Dr. W. F. P. McLintock and Dr. J. Phemister.—*On a Gravitational Survey by means of the Eötvös Torsion Balance in the Neighbourhood of Drumry, Glasgow.*

The drift-filled preglacial valleys of the River Clyde and its tributaries do not coincide entirely with their present courses. Borings north and west of Glasgow have shown that the preglacial Kelvin valley can be traced from Kirkintilloch to Drumry and that at Drumry the depth of the buried valley is at least 300 feet below the present surface or 240 to 250 feet below present Ordnance datum. The contour map of the rock surface round Glasgow which is contained in the Geological Survey Memoir on the Geology of the Glasgow District shows that at Drumry the buried valley of the Kelvin appears to fork against a rock mass which has been shown by boring to rise to within 74 feet of the surface. It was suggested that the outlining of this rock mass would be a suitable problem for solution by means of the torsion balance.

The survey was carried out in December 1927, and in January and February of this year. Sixty-eight stations were investigated. During the survey an area of one-quarter of a square mile was contoured at five-foot intervals to allow topographical corrections to be calculated. Since the problem is the investigation of a buried topography it is evident that no symmetrical results are to be expected and that, therefore, an areal survey is necessary. Stations were put down with a view to constructing an isogam map of the area, that is, a contoured map on which the contours connect all the positions at which the force of gravity has the same numerical value when normal earth and surface effects are eliminated. Owing to an insufficiency of stations in the west of the area it was possible only to construct the isogams for the eastern part. The isogam map indicates the existence of an embayed valley flank stretching north and south and falling to the east. Detailed analysis shows that in the locality where the gravitational evidence is most complete, the slope of the valley side is one in six. A bore in this neighbourhood shows 74 feet of drift, while the depth of drift at the mapped position of this bore is, from the gravitational results, about 80 feet. One of the embayments of the valley side is

sufficiently well defined by the isogams to permit the conclusion that the embayment is a gully approximately 70 yards wide and with a possible depth of 150 to 200 feet from the surface. A bore in this neighbourhood shows 114 feet of drift. So far the gravitational survey is in agreement with the facts known from boring and presented in diagrammatic form in the map in the Glasgow Memoir. This map shows north of Drumry a deep branch of the buried Kelvin valley stretching east and west. The isogam map, however, suggests the conclusion that the valley running from the east takes a right-angled bend to the south, while in the crook of the bend a westward-pointing bay has been formed. Owing to the unsuitable nature of the country north-west of Drumry there is no gravitational information available as to the westward extension of the buried valley, though there is mining evidence, one mile west of Drumry, that the drift reaches 140 feet below O.D. If such an extension exists, the results so far obtained by the Eötvös balance indicate that it will be at a considerably higher level than the floor of the valley in the Drumry bend.

Dr. G. Slater.—*The Structure of the Drumlins on the Southern Shore of Lake Ontario, New York State,* 1924.

The central-western part of New York State, south of L. Ontario, contains the finest development of drumlins in the United States. Within an area of 5,000 square miles there are at least 10,000 drumlin-crests, 6,000 of which are indicated on the fifteen topographical maps of the area. Scores of these drumlins are a mile in length, but only two exceed an elevation of 200 feet, the average height of thirty-one of the highest being 150 feet. The drumlins radiate from the south-eastern shore of the lake, and attain their greatest development in the adjacent low Ontario plain.

The sections which display the structure to best advantage extend from Sodus Point to Oswego, a distance of 28 miles. Of the score of drumlins in this stretch of shore-line, eleven are of especial interest. As a rule a lower ' core ' of boulder clay is overlain by stoneless clays, loams, boulder clay and occasionally lenticles of sand, showing ' concentric-bedding.' The drumlins are therefore composite in character, the two facies of deposits representing progressive stages of construction. The genesis of the structure appears to be as follows : In each of the drumlins the stranding of the lower boulder clay, of roche-moutonnée outline, led to a local pressure gradient and the plastering of later material over, and against, the flanks of the 'core,' movement being along thrust-planes. The area between the flanks of adjacent drumlins functioned as a zone of tension. This structure agrees with the principles of glacial tectonics described by the author at previous meetings (Brit. Ass. 1924, '26, '27). The expenses of this investigation were defrayed by a grant from the Sladen Trustees, 1924, for which the author expresses his thanks.

Mr. G. Ross.—*Glacial Phenomena in the Douglas Valley.*

Recent survey work in the Douglas Valley and the adjacent ground has in the main confirmed the work of the earlier investigators in this region. It has further shown that the oldest glacial deposits, the shelly boulder clay of the western, and the Highland boulder clay of the north-western parts of the area are overlain by the Southern Upland Drift.

The carry of the erratics of Cairn Table Sandstone, Spango Granite, and Crawfordjohn essexite show the main Southern Upland ice-movement to have been north and north-east in this region. Subsequently the direction of this ice-movement was determined by the grade of the Douglas Valley.

The trend of glacial striæ within the valley and of glacial drainage channels along its sides indicate the existence of a valley glacier originating in the wide amphitheatre bounded by the heights extending from Cairn Table to Spango Hill.

The fluvio-glacial deposits of the Douglas Valley are due probably to deposition by melt-waters along the margins of the shrunken valley glacier at a late stage in its dissolution, when drainage into the Clyde Valley was still blocked by ice.

Mr. J. B. Simpson.—*The Valley Glaciation of Loch Lomond.*

In the Loch Lomond district the terminal moraine of a large valley glacier has been traced by the writer almost continuously for fourteen miles, from Auchineck west-

wards along the northern slope of the Kilpatrick Hills to Bonhill in the Vale of Leven, and thence north-westwards by Tullichewan Castle, Auchindennan Muir, and Bannachra Muir to Inverlauren in Glen Fruin, at which point it turns north-eastwards, and ascends the slope of Shantron Hill. A corresponding morainic feature has been noted in Glen Finlas, and on the west side of the loch at various points between Rowardennan and Balmaha. The Glen Fruin section of the moraine has long been known, and has been described by Bell (1893), Renwick (1895), and Gregory (1907).

The complete absence of morainic deposits on the boulder clay outside the moraine and their abundance within it, the marked lobing of the moraine up valley outwards from Loch Lomond, and the manner in which it ascends to higher levels on hill slopes athwart the course of the ice stream, point to this glaciation being due to a distinct re-advance of the ice, and not merely a phase in the retreat of a larger ice-sheet.

Probably the main outlet of the melt-waters of the glacier was by the Vale of Leven gap. Here an extensive outwash fan of gravel has been deposited. Below the 50-foot level this was subsequently re-sorted, in a large measure by the sea that formed the Early Neolithic Beach. Above the height mentioned the fan sloped gently upwards and merges with hummocky gravel deposits within the moraine.

Interesting features *within the terminal moraine* are :

(1) A belt of gravel spreads and morainic mounds, the latter sometimes concentric with the outer moraine.

(2) A system of drumlins radially disposed with respect to the upper reaches of Loch Lomond.

(3) Marine shells, indicative of cold-weather conditions, widely dispersed in the boulder clay. This fact was first noted by Jack (1875) who, like the writer, attributed their presence to land ice dredging out Loch Lomond, an arm of the sea. These shells have been noted in new localities close up to the moraine ; but never in the boulder clay outside, which is otherwise similar to that within.

(4) South and east of Drymen, and resting on this shelly drift, a wide expanse of sand, gravel and laminated clays also with *marine* shells. Jack regarded these deposits as marine, and this view has lately been upheld by Gregory (1928). Geikie (1894) favoured a lacustrine origin for them, pointing out that the shells could be derived from the underlying shelly drift. Bailey (1925) strengthened this interpretation by drawing attention to an overflow channel near Balfron by which the waters of this postulated Drymen lake, held up by ice to the west and south, escaped eastwards. The writer agrees with the freshwater hypothesis, and in support of this advances the further point that the shells in the gravels are so widespread that it is unlikely that they are wholly derived from the drift, and it seems much more probable that they were dredged by the ice from the old sea-floor of Loch Lomond, carried forward as englacial material, and ultimately discharged by the melt-water into the Drymen lake.

At Inchlonaig, six miles from the foot of the loch, Craig (1900) records contorted shelly marine sediment at 100 feet overlain by boulder clay, and postulates a recrudescence of glacial conditions to account for this. The additional facts noted by the writer point to this re-advance of the ice being of much greater magnitude than was previously supposed. At Dumbarton on the Clyde estuary the 100-foot beach deposits are developed, and continuing up the Vale of Leven comparable sediments are traceable at intervals to within a mile of the moraine. No corresponding platform has been detected within this limit, and morainic mounds descend to a level of about 60 feet. From this latter observation we may conclude that the final retreat of the ice was not earlier than the emergence of the land that took place after the deposition of the 100-foot beach.

Mr. D. Tait.—*On the Occurrence of Peat or Lignite under Boulder Clay, near Glasgow.*

The deposit described was met with during the construction of the western part of the new Glasgow-Edinburgh road at a point about one mile east of Alexandra Park and a little south of Gartcraig House (one-inch Geological Map, Sheet 31 ; six-inch sheet Lanark vi S.E.). Here a cutting with a length of about 200 yards and a maximum depth at its centre of 12 to 15 feet was made through a low rounded mound. When newly exposed the section was as follows :—

		ft.	in.
(1)	Soil	1	0
(2)	Sand	1	0
(3)	Brownish sandy boulder clay: the lower 18 in. hard and concretionary and with an irony cement	10	0
(4)	Stiff bluish or greenish clay, with faint reddish tinge; almost stoneless, but with fragments of the underlying peat. (There were signs of disturbance at the junction of (4) and (5))	1	0
(5)	Peat or lignite, with abundant remains of beetles	1	2
(6)	Greenish stoneless silt	1	6
(7)	Compact boulder clay with many scratched boulders	0	9
(8)	Gap	about 3	0
(9)	Carboniferous shales.		

The peat or lignite (bed No. 5) is a hard, compact, laminated material, deep brown in colour and sometimes showing slicken-sided joint surfaces. It compares closely in appearance with some of the lignites of Germany. It is made up of flattened grass-like leaves and stems—no rounded woody stems were noted—and contains a profusion of beetle remains. The deposit does not occur as a regular bed, but as a layer of cakes of laminated lignite enveloped in clay and inclined in various directions usually at low angles. It is clear that it is not lying in the position in which it was formed; originally continuous it has been moved and broken up by the pressure of the over-riding boulder clay (bed No. 3). It indicates the existence at this locality of a marsh or loch, the deposits of which were disturbed during the readvance of the ice sheet and incorporated in part in the lower portion of the boulder clay. Similar peat beds have been noted elsewhere in Scotland, as for example, at Faskine, near Airdrie (*vide Trans. Geol. Soc. Glasgow*, vol. x, part 1, 1895, p. 148), and at Cowdenglen in Renfrewshire (*op. cit.*, vol. ix, part 1, 1891, p. 213).

The plants of which the lignite is composed have not yet been determined. The beetle remains in the lignite, which are abundant, have been submitted to K. G. Blair, of the British Museum, who has reported on them as follows :—

'Most of the species, or their very close allies, have previously been found in peat deposits though it is rather striking that *Donacia*, the genus usually most in evidence in peat deposits, is entirely lacking from the material now submitted.

'The three species most plentifully represented are *Patrobus septentrionis*, *Olophrum fuscum* and *Notaris æthiops*'—all northern forms.

Dr. G. Slater.—*Studies on the Rhone Glacier*, 1927.

The investigation of the Rhone Glacier by the author in 1927 was confined to two lines of inquiry : (1) The structure of the ice forming the concave side of the south-eastern flank of the glacier; (2) The relationship between the air-temperature and rate of the surface melting of the ice.

1. The surface of the marginal ice was marked into 50-foot squares, and the structure plotted on a map to a scale of 50 feet to an inch. The ice formed a mound dissected into ridges by three longitudinal, basin-shaped trenches, which were heavily crevassed laterally and bounded by crevasse-like walls of ice longitudinally. Thrust-planes dipping at high angles formed a characteristic feature of the ridges. In plan they formed radiating groups, the fulcrum of each group being near the margin of the lateral moraine. The trend of these thrust-planes varied progressively south-wards, from N.W.–S.E. to E.–W. approximately, and adjacent pairs formed the jaws of squeezed wedges of ice showing displaced ribbon-structure. Crevasses radiated from the lateral moraine and in places dissected the junctions of the thrust-planes. The structure as a whole suggests pivotal movement of the compressed marginal ice, the 'trenches' representing tensional areas due to the deviation in direction south-wards of the movement of the ice, from the normal south-westerly trend. Relief from pressure was obtained both laterally and longitudinally by the squeezing inwards of the ice towards the tensional areas on the one hand, and by the upward rising of the ice along thrust-planes on the other.

2. Observations in Spitsbergen, 1921 suggested to the author the following tentative relationship between the average air-temperature and the rate of melting of the ice :—

$$M=\frac{t^\circ-32^\circ\text{ F.}}{2}$$

where M=thickness (in feet) of ice melted per month (30 days), and $t°$=average monthly temperature (F.).

This would become ·2 inches of ice melted per day for each degree (F.) above zero under normal atmospheric conditions, wind and rain producing deviations from the normal. With the object of testing further this relationship, observations were conducted on the Rhone Glacier 1927 over a period of twenty days. A hole 3 feet deep was bored in the ice and a rod inserted from which a shaded standardised maximum and minimum thermometer was suspended. It was found that when hourly records of temperature were recorded the relationship given above was corroborated. As the recording of hourly temperatures, however, was impracticable, late morning or early afternoon temperatures only were recorded, in addition to the maximum and minimum.

An inspection of the tables of Zurich air-temperatures (Das Klima de Schweiz, 1864–1900) shows that the average of the maximum and minimum temperatures gives too high a value to the summer mean, whereas if the mean between the noon and maximum temperatures be first obtained, and then the mean calculated between this figure and the minimum temperature, the approximation to the true mean is more correct. This method was accordingly adopted. The average temperatures (July 26 to August 15) were as follows: maximum 50·6° F., minimum 34·5° F., noon 44° F., giving a daily average of 8·9° F. above zero. Assuming the rate of ·2 inches of ice melted per day for each degree, the total amount melted would be 35·6 inches. The actual amount was 35·2 inches. The expenses of this investigation were defrayed by a grant from the Royal Society, for which the author expresses his thanks.

Dr. W. K. SPENCER.—*The Starfish of the Scottish Palæozoic Beds.*

AFTERNOON.

Excursion to Barnley, Barrhead, and Paisley. (Leaders: Mr. P. MACNAIR and Mr. B. HILTON BARRETT.)

Saturday, September 8.

Excursion to Pinwherry and Girvan. (Leaders: Prof. J. W. GREGORY, F.R.S., and Dr. ETHEL CURRIE.)

Monday, September 10.

Presidential Address by Mr. E. B. BAILEY, M.C., Lég. d'Hon., on *The Palæozoic Mountain Systems of Europe and America.* (See p. 57.)

Discussion on *Problems of Highland Geology.* (Dr. GERTRUDE L. ELLES, Dr. H. H. READ, Dr. E. GREENLY, and others.)

Dr. GERTRUDE L. ELLES.—The main problems of Highland geology at the present are those relating to (1) the age of the beds; (2) the actual succession; (3) the relative ages of the various rock groups; (4) the metamorphism; (5) the complex of structures; (6) the age of the movements.

Most of these are intimately related but definiteness may be given to the discussion if arguments are directed along one or more of these lines.

Available evidence to date seems to indicate a close connection between the metamorphism and the fundamental folding which are regarded as part of the same story though the effects may be somewhat obliterated by the more obvious later folding.

Barrow was the pioneer in 1912 to show the significance of the metamorphic changes in the pelitic members of the Highland Schists, and his work holds, and has been extended though in some degree re-interpreted by Tilley and others, for his zones (or belts) of metamorphism are now regarded rather as due to depth than to contact with a body of igneous rock, though should the depth be reached at which permeation on a large scale by an igneous magma takes place, a superadded effect may result. The

index minerals of the different belts are, therefore, essentially stress minerals produced by changes in the pressure and temperature at different depths. Thus there is an outermost belt or zone characterised by the production of (1) Chlorite, and at successive depths (2) Brown Biotite, (3) Almandine Garnet, (4) Staurolite, (5) Kyanite, and (6) Sillimanite may be found, though the last appears to be produced most extensively in the permeation area.

This regional metamorphism appears to be intimately connected with the structure of the Central Highlands, and since it has been shown that these belts or zones can in many cases be mapped across Scotland from sea to sea (Tilley), it is held that any account of structures that fails to take into account the metamorphic condition of the beds must be regarded as incomplete. This intimate connection can be well illustrated by reference to the Corval-Loch Fyne area, and the Loch Tay area, where any departure from the normal succession of the metamorphic belts is found to have an explanation in structure.

In regard to the age of the different movements, the earlier, which is held to be Pre-Cambrian, is accompanied by features indicating formation at a considerable depth, whilst the later shows features suggestive of formation under relatively *superficial* conditions, such as those accompanying the big fault-lines that cross the C. Highlands, *e.g.* Loch Tay Fault, the Bridge of Balgie Fault, the Tyndrum Fault and the Glen Stru Fault. These are essentially overthrust faults, in some cases accompanied by true mylonites with a movement towards the N.W. It is suggested that these may be the result of the Caledonian Movement upon the earlier folding; marked torsion of the rocks as a whole may also result as in the case of the Schiehallion torsion and the Beinn Douran torsion. Other evidences of the age of later movements might be found along the Highland Border.

Dr. H. H. Read.—Each advance in our knowledge of the Dalradian of the North-east Highlands appears to force us into a closer comparison of that region with the South-west. Several years ago attention was directed to certain leading features in the Dalradian geology of Lower Banffshire and North-west Aberdeenshire, namely :—

(1) The occurrence in the Banff Division of somewhat peculiar rock-types, and possibly of lavas, recalling types well-known in the Loch Awe Group of the South-west Highlands.

(2) The correlation of the Keith Division with certain Perthshire Dalradian groups.

(3) The differing types of metamorphism in the Banff Division and in the underlying Keith Division.

(4) The separation of the Banff and Keith Divisions by a line of discontinuity (the 'Boyne Line').

(5) The synclinal structure of the Banff Division.

From these features it was suggested that the Banff Division and the Loch Awe Group were comparable in local structure.

Recently two investigations have been completed that have a bearing on this suggestion. It has been shown that the Deeside Limestone is probably the equivalent of the Loch Tay Limestone, and that this limestone disappears in Deeside owing to the northwardly-pitching Cromar Anticline. The Banff Syncline thus appears to be definitely asymmetrical, having on its west side the equivalents of the Ben Lawers Schist-Blair Atholl Limestone portion of the Perthshire sequence and on its south-east side the Ben Lawers Schist-Pitlochry Schist portion of that sequence. This asymmetry recalls the asymmetry of the Loch Awe Syncline, which E. B. Bailey has explained on the nappe hypothesis. A possible explanation of the asymmetrical Banff Syncline may be, therefore, that it is a structure affecting a nappe, the Banff Nappe.

Further, the recognition by E. B. Bailey of the Perthshire Culmination may supply, as it were, a plane of symmetry for the whole Dalradian structures. It may be suggested that to the north-east of this culmination the north-easterly pitch brings on the Banff Nappe, whilst to the south-west the south-westerly pitch brings on the Loch Awe Nappe. To establish the existence of the Banff Nappe and to demonstrate its equivalence to the Loch Awe Nappe may be the reward of further work.

Dr. E. Greenly.—Evidence available in Anglesey seems to throw light on Highland problems.

Recent work fully confirms the view that the Mona Complex is of pre-Cambrian age, which seems to throw the burden of proof upon those who would deny that the same is the case in the Scottish Highlands. Confirmation has also been obtained

for the view that the bedded succession of the complex rests unconformably upon its Gneisses; and as it is certain that there are schists of sedimentary origin which are older than the deposition of the bedded succession, corresponding relations may be looked for in Scotland.

I once put forward the view that the dominant anamorphism of the complex is not a product of the recumbent but of the later foldings. I now find this to be an error. The dominant anamorphism is certainly older than the major secondary folding, so the same is likely to be the case in Scotland. Many more stages in the metamorphic process have been disentangled, so many may be expected in Scotland.

The existence of the Bodorgan anamorphic minimum in Anglesey is a warning against assuming that the boundary of the Scottish anamorphism is approached at the Highland boundary fault.

With due caution correlation of beds does not seem to be impossible between the two regions.

In Anglesey coincidence between the directions of the Palæozoic and the pre-Cambrian movements turns out to be no more than a simulation. May not the coincidence in the Highlands be likewise a simulation ?

Thus Anglesey seems to create at least presumptions in regard to Highland problems.

But in view of the probability of deceptive structures let us, in both regions, hold our theories 'with a loose hand.' I have advocated the theory of recumbent folding for the Mona Complex, and I still do so. In regions such as these, however, may there not be some hidden principle whereof we have no more idea at present than our predecessors had of recumbent folding ?

AFTERNOON.

Excursion to Victoria Park, Fossil Grove, Bowling, and Dumbarton. Leaders: Dr. G. W. TYRRELL and Mr. P. MACNAIR.)

Tuesday, September 11.

Discussion on *The Tectonics of Asia.* (Prof. F. E. SUESS; Dr. D. J. MUSHKETOV; Prof. J. W. GREGORY, F.R.S.; Prof. DE BÖCKH; Prof. G. P. BARBOUR; Prof. H. A. BROUWER; Mr. F. WEST.)

Prof. F. E. SUESS.—The horsts of middle and western Europe which Suess has considered as fragments of a branch of the Asiatic Altaids, are composed of different elements. To the north they contain the remnants of a fold zone with far-reaching thrustfolds of Alpine dimensions, the Variscan-Armorican arc proper. The broad middle region that comprises the bulk of the Bohemian massif, the Black Forest, the Vosges and the French Central Plateau, shows a peculiar structure which is called the 'Intrusion tectonics'; it is characterised by the great extension of granitic intrusions, by the lack of general strike and by the post-tectonic crystallisation of the schists with the mineralogical constituents of the katametamorphism. Other folded structures of Alpine type with the corresponding crystalline facies of the schists are attached to the Bohemian massif on the east and to the French Central Plateau on the west.

The field of intrusion tectonics in the European horsts represents one gigantic chip splintered from the roof above the 'Sal' and pushed forward by great tangental forces. The folded range in front of this large block is an effect of this movement.

We may learn from the data of these and similar regions that in any crystalline complex to work out trendlines of geological structure the careful study of the type of metamorphism is indispensable, and we may expect that also the pre-Permian basement complex of Central Asia will contain a great variety of structures and a considerable portion of them will have to be attributed to the intrusion tectonics.

It is hardly possible to establish definite connecting lines between the pre-Permian structures that have been distinguished as European and Asiatic Altaids.

In Europe, as in Asia, the old structures have been overwhelmed by the younger tangential movement, and in the European horst-region, as in many parts of Central Asia, the actual morphology is related to transverse disturbances sometimes of great

extent. This younger movement is chiefly block-movement of older previously folded material forming 'folded mountainblocks' in the sense of *Obrouchev* or 'groundfolds' in the sense of *Argand.*

Among other fault-systems in the horst-region that of north-western direction is far prominent. Suess has it comprised under the name of the Asiatic or Karpinskyan lines. If we admit that the folded mountainblocks of the present Asiatic morphology are produced by the great tangential push in relation to the southward creep of the enormous crustal sheet, we have also to consider the north-western fault-system in Europe as the deflected and diminished effect of the same process.

The unifying attribute of the Altaids is their common pre-upper-Carboniferous age. But they may contain structures of various trends and of various ages.

Afternoon.

Excursion to Aberfoyle and Loch Chon. (Leader: Prof. J. W. Gregory, F.R.S.)

Wednesday, September 12.

Mr. A. G. Macgregor.—*Metamorphism around the Lochnagar Granite, Aberdeenshire.*

These preliminary notes give some of the results of a detailed study of the Dalradian Schists adjoining the margins of the 'newer' granite and diorite of Lochnagar and Glen Doll; the work is not yet completed.

The district is included in a Geological Survey 'one-inch' colour-printed map (Sheet 65) and described in the accompanying memoir.[1] In the areas under discussion these publications largely represent the work of Mr. George Barrow, whose accurate mapping of rock-outcrops has made 'Sheet 65' an invaluable asset for his successors.

According to Mr. Barrow's views, as expressed in the Sheet 65 Memoir, the metamorphism of the Dalradian Schists is everywhere a regional thermal phenomenon of earlier date than the intrusion of the 'newer' granite and diorite and their associated dyke-suite. He states repeatedly that the 'newer' intrusions have produced little or no reconstructive effect on the rocks which they cut. I believe this standpoint to be untenable. It should be noted that Mr. Hinxman and Mr. Cunningham Craig, in the ground described by them in the Sheet 65 Memoir, attribute marked contact-metamorphic effects to the intrusion of the 'newer' granites and diorites.

North of the River Dee, between the Slugain and Feardar Burns, Mr. Barrow has shown that the Black or Dark Schist Group has a hornfels aspect and contains cordierite, andalusite, sillimanite and spinel. In my opinion the evidence points to the numerous local intrusions of 'newer' granite and diorite as the cause of the presence of the above-mentioned 'contact' minerals in the metamorphosed sediments. This view is greatly strengthened by the recognition of severe contact-alteration in a small dyke cutting the schists. This intrusion belongs to the suite of 'newer' dykes, and its contact-metamorphism must therefore be attributed to the 'newer' granite and diorite.

Further south, in Glen Callater, I have found contact-metamorphosed rocks, originally resembling members of the suite of 'newer' dykes, enclosed in the 'newer' granite of the edge of the Lochnagar mass. It can moreover be demonstrated that the Lochnagar granite has here severely baked the Black or Dark Schist for at least 100 yards from its margin, and has produced considerable mineral reconstruction. Cordierite is abundant, large andalusite porphyroblasts are constantly present, and sillimanite is sometimes found. Close to the granite margin kyanite (produced by pre-'newer' granite regional or regional-thermal metamorphism) is pseudomorphed by andalusite. Shimmer aggregates around regional kyanite and staurolite have been converted into cordierite. The metamorphism of the Black or Dark Schist of Glen Clunie at some distance from the 'newer' granite margin is too complex to be discussed here. I believe, however, that contact-effects superposed on an earlier metamorphism are not confined to the inner belt of andalusite-bearing rocks.

[1] 'The Geology of the Districts of Braemar, Ballater and Glen Clova' (*Mem. Geol. Surv. Scotland*), 1912.

The 'newer' diorite complex of Glen Doll has been intruded into injection-gneisses—schists intimately injected by Mr. Barrow's 'oligoclase-biotite-gneiss,' a phase of his 'older' magma. Close to the north-west and east margins[1] of the Glen Doll complex these injection-gneisses have been converted into a variety of almost completely reconstructed hornfelses containing cordierite, andalusite, sillimanite, spinel, corundum, &c. The reconstruction is much more marked than in Glen Callater. The change in character of the injection-gneisses as the diorite margin is approached is clear both in the field and under the microscope.

Dr. R. Campbell.—*The Composition of the Conglomerates of the Downtonian and Lower Old Red Sandstone of the Stonehaven District.*

A general account of the conglomerates of the Downtonian and Lower Old Red Sandstone of south-eastern Kincardineshire has already been published.[2] The present communication summarises the results of more detailed investigations, the following tables giving the percentages of boulders in a representative series of conglomerates. The term 'Caledonian' is applied to the volcanic rocks because the vulcanicity associated with the Caledonian movements was initiated prior to the deposition of the basement conglomerates of the Lower Old Red Sandstone. The figures are based on systematic laboratory examination of over 5,000 boulders, a large proportion of which have been examined in this section.

		Caledonian Lavas.	Caledonian Hypabyssal.	Caledonian Plutonic.	Highland Border.	'Highland.'
Downtonian :						
	Cowie	64	30	1	0	5
Lower Old Red Sandstone :						
Dunnottar Group.	Stonehaven Harbour ...	26	7	3	22	42
	Dunnottar Castle ...	12	18	31	13	26
	Tremuda Bay. .	21	3	18	1	57
Crawton Group.	Todhead ...	16	16	12½	12½	43
	Hallhill ...	81	0	2	0	17
	Little Johnshaven ...	33	0	4	61	2
	Grange Burn ...	55	1	7	36	1
	Gourdon ...	10	4	5	69	12
Arbuthnott Group.	Crawton ...	41	6	19	7	27
	Bervie Brow ...	22½	16½	11½	22	28½
	Black Knap ...	25	19	11	14	31
	Catterline ...	21	22	17	21	19
	Johnshaven ...	25	19	13	9	34
	Fairy Knap ...	82	0	5	0	13
	Barras Chapel...	78½	0	0	0	21½
	Biddrie ...	99	0	0	0	1
	Clatterin' Brigs	96	2	0	0	2
Garvock Group.	Forthhill ...	22	19	13	5	41
	Davo	25	19	8	20	28
	Canterland ...	15	16	4	30	35
	Balmakelly ...	13	14	10	14	49
	Burnhead ...	10½	29	0	10½	50
	Fasque ...	4	4	18	0	74
	Strathfinella ...	13	0	4	0	85

[1] I have not yet studied the southern margin.
[2] *Trans. Roy. Soc. Edin.*, vol. xlviii., p. 923, 1913.

Taking the total collection of boulders we find that the rock groups of the above tables occur in the following proportions :—

		%
Caledonian igneous rocks	Lavas	31
	Hypabyssal	12
	Plutonic	$8\frac{1}{2}$
Highland Border Series		15
Other 'Highland' Metamorphic Rocks		$33\frac{1}{2}$

Approximately half of the boulders consist of igneous rocks which are products of the Caledonian magma. A very large proportion of the effusive types are not represented in the local Old Red Sandstone volcanic succession. It is inferred that they have been derived in part from a suite of volcanic rocks which formerly mantled the Dalradian area. Boulders of the 'Buchan Ness Porphyry' are so abundant as to suggest the denudation of great sheets of that rock which has now a much restricted distribution. The large percentage of Highland Border rocks clearly points to a much wider distribution of these at early stages in the denudation of the Caledonian Mountain chain. Of particular interest is the discovery of several boulders of a fossiliferous limestone similar to the Margie limestone of Aberfoyle.

The chief interest of the 'Highland' boulders centres in the support their distribution gives to the idea of progressive depth metamorphism. The sillimanite and staurolite gneisses of the southern highlands appear first in the highest conglomerates of the Garvock group.

Dr. D. A. Allan.—*A Preliminary Account of certain Lower Old Red Sandstone Conglomerates in Perthshire and Forfar.*

The Lower Old Red Sandstone sequence along the fringe of the Grampians in Perthshire and Forfarshire consists of lava flows and conglomerates with an overlying group of sandstones. Owing to the scarcity of fossiliferous horizons, reliance has had to be placed upon persistent groups of lavas in the mapping of the area. As the general order of the lavas appeared invariable, an investigation was made of the composition of the intervening beds of conglomerate which fall into five well-defined groups, forming with the lavas a stratigraphical sequence.

In the valley of the upper Ericht and the adjacent Ardle local basement conglomerates intervene between the lowest lavas and a floor of steeply folded Dalradian schists. The material consists in the main of vein-quartzes, schistose grits and mica-schists, together with a small quantity of igneous rocks, in part probably basic lava flows and in part intrusions.

Above the lowest lava group is a second series of conglomerates the material of which is almost exclusively of igneous origin. It is in part closely similar to that of some of the underlying basic lavas, but the majority of the pebbles consist of acid rocks of general lava-form character, the parent mass of which has not been identified within the district.

The third group of conglomerates is again predominantly igneous in complexion, but the content of basic volcanic rocks is greater than that of the acidic varieties, and there is always present metamorphic material of Highland origin.

The fourth set of conglomerates overlies the highest group of lavas, and is composed almost entirely of basic igneous rocks. Above it, but separated by a fairly persistent band of sandstones, is the fifth and highest conglomerate belt, characterised by a very high content of quartzites, schistose grits and vein quartzes.

With the exception of the first, which is of comparatively limited distribution, these conglomerate belts can be traced for long distances, and are therefore useful stratigraphical indicators. The general trend of variation in their composition is indicative of the denudation of a landmass of Dalradian schists which was later covered by extensive sheets of igneous rock, in their turn also subjected to erosion. The reversion to Highland material shown by the youngest Lower Old Red Sandstone conglomerates suggests that denudation had again reached the Dalradian basement. Contemporaneous erosion has been demonstrated in certain field exposures. A statistical examination of the composition of the conglomerates bears this out in a very striking way. While schists showing a relatively high grade of metamorphism are most abundant in the lowest conglomerates, pebbles of granite, &c., do not appear until much higher in the sequence. It is possible, however, that the wide distribution of mica in the higher sandstones reflects the more complete destruction of such Dalradian material, consonant with the greater distance it had travelled.

Dr. W. Mackie.—*Preliminary Report on the Heavy Minerals of the Silurian Rocks of Southern Scotland.*

About fifteen specimens of greywacké were collected in the spring of 1926 from an area round the town of Peebles of about two miles' radius, and the heavy minerals isolated from them gave unexpected results. All of them were found to be 'flooded' with particles of a fine greenish to greenish-yellow augite, which often showed characteristic inclusions. Along with these was a proportion of hornblende and enstatite fragments, but these were always in relatively much fewer numbers. These residues also contained garnet, sphene, and almost always zircons, both coloured (*purple*) and colourless with, in addition, some apatites, epidotes and tourmalines. In these were also observed numerous minute angular fragments of a glossy dark brown colour often exhibiting conchoidal fracture, and which were found to be uniformly isotropic, but they were so insignificantly small that their true import was at first overlooked. They were later found to occur in marked excess in the rocks to the south-west of the area, and have since been referred to the mineral melanite. A fairly large number of specimens have since been collected and their content of heavy minerals specifically determined, but up to the present these cannot be said to represent more than a small fraction of the entire area, but typical specimens have been examined at intervals along the northern margin of the area from Peebles to Ballantrae and from the latter locality across the strike to the Rhinns of Galloway and Glenluce. Occasional specimens from the rest of the area, chiefly for the purpose of comparison, have also been examined.

Over all the results from sixty-one specimens have been tabulated with the following results :—

Thirty-four out of 61 showed the presence of augite, 22 hornblende, 14 enstatite, 52 zircon (of which 34 contained *purple* zircons), 38 garnets, 19 sphene, 38 melanite,[1] 5 glaucophane, 21 epidote, 23 apatite, 16 tourmalines, 18 rutile, 7 pyrite, 11 chlorite, 2 anatase and 1 each of brookite, magnetite, dolomite, fluor and hypersthene.

The feature of the minerals generally is their remarkable freshness, which is evidently due to the relative impermeability of the Silurian rocks. Augite is not a mineral that figures largely in heavy mineral residues, while melanite is probably unique in its occurrence, both as regards extent and quantity. Both of these minerals are very widely distributed, but it is doubtful if they were originally associated in one and the same rock mass because melanite is present often in abundance where augite has not so far been found. They occur in such abundance and over so wide an area that the natural inference is that they were derived from rock masses of considerable superficial extent outside the existing area of Silurian rocks.

The above list of minerals is also interesting from the negative side—monazite is so far entirely absent from the list. There is also no kyanite, staurolite, sillimanite or andalusite.

It may be somewhat premature to attempt to indicate the possible origin of the Silurian sediments, but a large area of basic volcanic or plutonic rocks is suggested. The Ben Ledi grits evidently came into the area, as may be inferred from the frequent presence of chlorite, tourmaline and purple zircons[2] in association, these being the characteristic minerals of the Ben Ledi grits, while the only known occurrence of glaucophane in mid-Scotland is in these rocks. From the number of characteristic, colourless and generally unworn zircons that appear locally in the south-west of the area, a foliated granite[3] (or granites) also appears to be indicated.

Mr. E. H. Davison.—*The Geology and Economics of the West of England China-clay Deposits.*

China clay has been worked in Cornwall and Devon since the beginning of last century, and the industry has now developed to such an extent that 800,000 tons were produced in 1927.

The china clay rock from which the china clay is obtained, occurs in all the granite

[1] It has been determined that the mineral is *not melanite.* What it is has not so far been ascertained.

[2] 'The source of the Purple Zircons in the Sedimentary Rocks of Scotland.' *Trans. of Edin. Geological Society*, vol. xi, part ii, p. 200.

[3] 'The Heavier Accessory Minerals in the Granites of Scotland.' *Edin. Geological Society,* vol. xii, part i, p. 22.

outcrops of the West of England, but especially in the western half of the Hensbarrow granite.

China clay rock is an altered granite in which the felspar has been more or less completely changed to kaolin or to amorphous hydrated aluminium silicate. It occurs along the strike of fissure lodes, and has been formed by the action of solutions of magmatic origin. The evidence for this statement may be summarised as follows :—

(1) The china clay rock is more completely kaolinised near the fissure lodes, 'stent' lodes, and the completeness of kaolinisation increases with depth.

(2) The occurrence of the china clay is associated with the occurrence of such minerals as tourmaline, gilbertite and sericitic mica.

(3) The physical characters of the West of England china clay are markedly different from those of clay of obvious meteoric origin.

(4) Clay deposits occur with a cover of unaltered granite.

(5) Though clay deposits have been worked to a depth of 350 ft., no instance is known of a deposit dying out in depth.

The china clay is washed from the china clay rock by means of monitors, the sand settled in a pit and the clay water pumped to surface and run through a series of long narrow channels, where the fine mica is settled together with any coarse clay and fine quartz. The clay is then settled in large tanks and afterwards transferred to larger tanks about 60 ft. × 40 ft. × 8 ft., which are usually situated along the mineral railway. All water is returned to the clay pit as a shortage of water would stop or seriously hinder production.

After settling the clay is transferred to a shallow pan heated by hot air flues below.

China clay is of various grades : paper or bleaching clay, which sells at 45*s*. to 65*s*. a ton ; potting clay, which sells at 25*s*. to 45*s*. a ton ; and the product of the first settlement, which is called 'mica,' and sells for 17*s*. to 22*s*. a ton if of good quality.

The cost of producing the clay is very variable, but is never less than 20*s*.—more often 25*s*. to 30*s*.—so that the quality of the clay produced is an important factor. The better clays are, moreover, easier to market than the lower qualities.

The percentage of clay produced from the china clay rock is sometimes as low as 10 per cent., while 35 per cent. is a maximum.

The clay industry is controlled by two associations, one dealing with best quality clay only, the other with inferior clay. These associations limit the output of each company in accordance with the market, but guarantee to each company the sale of a quantity of clay proportionate to the average sales of the year.

Mr. G. Vibart Douglas.—*Some Geological Relationships of the Pyritic and Cupreous Ore-bodies of Huelva, Spain.*

The ore-bodies may be grouped as : (*a*) contact bodies between porphyry and slate, with the ore either on the flank or as a roof pendant of the porphyry ; (*b*) massive sulphides entirely in slate ; (*c*) stockwork and disseminated sulphides entirely in porphyry ; (*d*) veins carrying sulphides (of minor importance).

The present land surface, being a chance surface by erosion, the ore-bodies of the province, as grouped in this classification, represent various horizons rather than isolated types. Thus the idealized section would show a stockwork porphyry passing into massive sulphides on the contact of the porphyry and the country rock (slate, grits, &c.). Above this zone, and entirely in slates, there would be lenticular bodies of sulphides. The outermost manifestations of mineralization are veinlets of quartz which may carry sulphides. There are numerous examples which illustrate these types.

With regard to the genesis of the ore-bodies the evidence favours hydrothermal replacement.

The general sequence of events is as follows :—

(1) Intrusion of porphyry as dyke and sill into a belt of Lower Carboniferous slates. The cleavage of the slate has a very regular strike and dip, and this has been the controlling factor in the geographical distribution.

(2) Auto-shearing and brecciation of the porphyry during injection.

(3) Alteration of the slates by intrusion of the porphyry, especially where the contact of the porphyry undercuts the slaty cleavage.

(4) Major fracturing of the porphyry, the result of movements of the magma producing torsional effects in the non-sheared crystallized porphyry.

(5) Injection of hydrothermal solutions along the major fracturing and shear zones. These solutions are thought to be derived from the parent magma, to which the porphyry belongs.

(6) Replacement by these solutions of altered and comminuted slate and porphyry.

(7) Erosion, oxidation and secondary enrichment of the ore-bodies. Supergene alteration of the porphyry.

SECTION D.—ZOOLOGY.

For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 685.)

Thursday, September 6.

Presidential Address by Prof. W. Garstang on *Larval Forms: their Origin and Evolutional History.* (See p. 77.)

Prof. J. H. Ashworth, F.R.S.—*The Distribution of Anopheles in Scotland, with remarks on Malaria in Scotland.*

Three species of Anopheles occur in Scotland (as in England): *maculipennis, bifurcatus* and *plumbeus.*

Maculipennis is recorded from four localities all in the Highlands; it has recently been taken near Kelso. Information on this species is far too scanty to support any general statement as to its range; many more areas need to be examined and careful inspection made of cowsheds, pigsties, stables and outhouses. *Bifurcatus* is known from about forty different localities; this species is widespread both in the Lowlands and in the Highlands. The localities in which *A. plumbeus* has been collected are in proximity to the east coast or its estuaries, but it is to be remembered that, except for the Clyde area, the west is practically unexamined.

A. bifurcatus proved so troublesome by its bites in one of the districts in the county of Renfrew in autumn 1926 that it became a nuisance within the meaning of the Public Health (Scotland) Act. Certain ditches, obstructed by silt and vegetation, were ordered to be cleared, and this has resulted in the abolition of the breeding places.

Ague was common in the eighteenth century in Roxburghshire, Berwickshire, the Carse of Gowrie and Forfarshire, and was widely distributed though less common in Aberdeenshire and the neighbouring counties (Dr. J. Ritchie). Unfortunately, the distribution of Anopheles in none of these areas is known, so that there is no basis for a consideration of the present distribution of the species of Anopheles in relation to the former distribution of ague.

I know of only two indigenous cases of malaria in Scotland in recent years: one in Forfarshire in 1919 and one (unpublished) in a south-western county in 1910.

Mr. C. W. Parsons.—*The Conus arteriosus of Fishes.*

It is difficult to delimit the pericardiac cavity in Cyclostomes; in adult Myxinoids indeed, the posterior pericardiac wall is represented only by a rudiment. In most fishes, however, the heart is confined within a pericardiac cavity having well-developed walls. The hearts of a number of forms have been examined, including Raia, Acanthias, Pristiurus, Lepidosteus, Polypterus, Ceratodus, Protopterus, Acipenser, Amia, Megalops, Symbranchus, Gymnarchus, Loricaria, &c., and particular attention has been paid (1) to the musculature of the structure intervening between the ventricle of the heart and the headward boundary of the pericardiac cavity, *i.e.*, the conus arteriosus; (2) to the character, number and position of the endocardiac ridges or valves that the conus contains. The headward boundary of the pericardiac cavity has been regarded as a fixed point and the morphological position of the valves &c. (dorsal, ventral, right, left) have been worked out in relation to it. The course of evolution in two directions is indicated. (1) Towards multiplication of the number of valves, conus contractility retained; (2) towards reduction of valves, conus contractility lost. The bearing of these observations on the general question of the evolution of fishes has been considered.

Miss A. M. Bidder.—*Yolk Absorption in some Cephalopoda.*

In all Cephalopoda whose larval or embryonic forms are known, the development is profoundly influenced, until an unusually advanced stage, by the presence of a large mass of yolk. A portion of this yolk, which increases as development proceeds, is contained in a yolk-sac within the animal. In *Loligo* (the type considered in detail) it has been found that three separate methods are successively employed to absorb this great mass of yolk. These methods are not constant throughout the group, but show, in *Sepia*, interesting modifications, while *Sepiola* appears to be in this respect intermediate between *Sepia* and *Loligo*.

Reports of Committees.

Afternoon.

Mr. E. R. Gunther.—*The Plankton of a Sub-Antarctic Whaling Ground.*

The food of the ' Whalebone ' whales is planktonic, and that of the great Blue and Fin whales has been shown in the south to consist almost entirely of one species of Euphausian, *Euphausia superba*. A study of the plankton, therefore, is of great importance in investigating the natural history of these whales.

The *Discovery* Expedition, in addition to carrying out, over the Southern Atlantic, general plankton investigations which have shown this species *E. superba* to be confined to the shallow waters of coast and islands, made an intensive plankton survey on the whaling grounds. That at South Georgia is described and the provisional results discussed. The Euphausians and the diatoms upon which they feed are shown to have a somewhat curious distribution : the former concentrated in dense swarms on the N.E. side and the latter in an encircling band round the island, having a maximum density on the S.W. side. Chemical and mechanical causes are suggested to account for this and the general richness of this whale feeding-ground. South Georgia is a long island peculiarly placed at right angles to the west wind drift so that upwelling of water rich in phosphates may give rise to the thick diatom growth which, carried round either end, feeds the Euphausian ' Nursery ' in the sheltered water of the other side.

The general ecology of the plankton is briefly discussed.

Mr. N. A. Mackintosh.—*Discovery Expedition Work at Whaling Stations.*

The objects of making a systematic examination of whales at whaling stations are first to procure evidence as to their specific identity and secondly to investigate the reproductive processes and breeding habits. One thousand six hundred and eighty-three whales, mostly Blue and Fin whales, were examined at South Georgia and South Africa between February 1925 and April 1927. Work on their specific identity will not be described at present, as the results are incomplete, but some aspects of the breeding of whales can be described. The proportion of immature whales is rather high, particularly among those captured off the African coast. The theory that breeding occurs mostly in the southern winter has been fully confirmed and evidence from the reproductive organs and records of fœtuses point to June and July as the height of the breeding season. The period of gestation in these whales lasts slightly less than a year and the nursing period about seven months. Whales probably become adult about two years after birth. The work has also thrown some light on the distribution, movements and segregation of the whales.

Prof. A. C. Hardy.—*On the Unevenness of Plankton Distribution and the Results of the New Continuous Plankton Recorder.*

Our knowledge of the density and distribution of the oceanic drifting life—the plankton—is usually gained from samples taken at a number of distinct stations within the area concerned. These stations, if the area is at all extensive, must necessarily be at considerable distances apart, so that we may doubt whether, owing to the patchiness of the plankton, the samples give a true idea of its distribution. Experiments have been made on the *Discovery* Expedition with a new instrument which will give a continuous record, mile by mile to scale, of the plankton in the water

traversed. The instrument is described and the results—records totalling some 2,400 miles—discussed; considerable patchiness is shown even in oceanic waters.

More detailed researches into patchiness were made by means of a series of consecutive tow-net hauls which revealed remarkable patches of Euphausians and Hyperiid Amphipods. The causes of uneven distribution are discussed.

Mr. R. Elmhirst.—*On the Work of the Millport Laboratory.*

A short account of the history and equipment of the station, with mention of the natural advantages due to its geographical position. The purity of the water supply in the aquaria is exceptional, giving special facilities to the experimental biologist. The scope of past work indicated and an account of recent investigations, chiefly planktonic, will be given.

Miss P. M. Jenkin.—*A Preliminary Account of an Investigation of the Plankton of Loch Awe in relation to the Physical and Chemical Conditions of the Water.*

Friday, September 7.

Dr. O. W. Tiegs.—*On Neurofibril Continuity.*

While it seems quite clear that ultimately there must be discontinuity in the integrating region of a reflex arc—in the sense that an impulse must pass from a region where conduction in both directions can occur, to one where forward conduction alone takes place—it does not follow that such discontinuity is in the form of a visible gap between the terminal branches of a neurone and the next cell of the chain. The author finds that in spinal cord cells, Mauthner cells, and cells of the ventral acoustic nucleus of fish, no visible gap in the neurofibril chain occurs, and that blind endings of neurones are due to incomplete staining.

Dr. E. Stedman.—*The Reversible Combination of Hæmocyanin with Oxygen.*

Hæmocyanin is a protein containing copper, present in the blood of certain invertebrates. It combines reversibly with oxygen, and is practically colourless in the reduced condition and blue in the oxidised. A study under carefully controlled conditions of the oxygen dissociation curves of the hæmocyanins from a number of species (*Cancer pagurus, Homarus vulgaris, Limulus polyphemus, Helix pomatia*) has revealed such marked differences in their behaviour towards oxygen as to leave no doubt as to their specificity. The affinity for oxygen of the hæmocyanins from *Cancer* and *Homarus* varies considerably with the hydrogen-ion concentration, and is found to be related to the viscosity of the solution, the affinity curve being antibatic to the viscosity curve. In the case of the pigment from *Cancer*, the pH (7·3) at which the viscosity of its solutions is at a maximum practically coincides with the pH at minimal affinity, from which it would appear that the affinity for oxygen of the hæmocyanin anion is smaller than that of the undissociated pigment. On the other hand, the power of the hæmocyanin from *Helix* to combine with oxygen is, in salt-free solutions, uninfluenced by pH. The curve is, moreover, of the hyperbolic type, which would be expected if the pigment were molecularly dispersed in solution and combined with oxygen according to the equation $\mathrm{H}cy + \mathrm{O}_2 \rightleftharpoons \mathrm{H}cy\mathrm{O}_2$.

Prof. A. D. Peacock.—*Parthenogenetic Male and Female Production by two kinds of Females in one and the same Species of Sawfly.*

From larvæ collected in Nature both sexes of the saw-fly *Thrinax macula*, Kl., have been reared, the sex-ratio being 100 males : 560 females. The males emerged and died before the advent of the females, so that sexual reproduction could not be studied. However, from thirty-four experiments with single virgin females, both sexes have still been obtained by parthenogenesis, the sex-ratio being 100 males : 290 females. Of these 34 parthenogenetic females 3 gave non-viable larvæ, 27 gave females only (thelytoky) and 4 gave (to date) respectively 22 males and 1 female.

9 males and 1 female, 3 males, and 1 male. For reasons to be given the appearance of these 'occasional' females is not regarded as controverting the idea that the mothers were really male-producers (arrhenotokous). The species is therefore predominantly thelytokous. So far four successive parthenogenetic generations have been obtained, but the significance of male-production remains undetermined.

In saw-flies the parthenogenetic production of both sexes by the same female, where undue preponderance of one or other sex does not obtain, is known in two species only. The case discussed here is different, and is a new record, for the two sexes are produced by two kinds of females, one kind male-producing and the other female-producing. The biological significance of this will be discussed.

Dr. G. S. Carter.—*The Structure of the Ciliated Cells of the Velum in the Veliger of Aeolidia papillosa.*

The nerve-supply and the cytoplasmic structure of these cells has been investigated as far as possible in fresh material by the use of vital stains. Intracellular nerve-fibrils were found, ending near the basal granules and connected with the nerve-supply described in a previous paper. The cilium is complex and consists of numerous simpler units. Each of these consists of an external fibre, a basal granule and two similar structures in the cytoplasm of the cell, and of a columnar element of protoplasm passing inwards from the base of the external fibre. One of these units, and not the whole cilium, is the true unit of ciliary activity in these cells.

The chemical nature of these structures as displayed by histo-chemical reactions was investigated. The basal granules contain lipoids and probably also carbohydrates. Lipoid vacuoles of two types are present in the cytoplasm of the cell. Those of one type are large and lie near the base of the cell, and appear to contain the reserve food-materials of the cell. Those of the second type lie near the ciliary apparatus, contain fatty acid, and can be seen to circulate around the part of the cell in which they lie. They appear to play some part in the activities leading to the beat of the cilium.

The bearing of these observations on recent theories of the chemical mechanism of ciliary activity is discussed.

Mr. A. D. Hobson.—*Some Aspects of the Relation of Salts to the Unfertilised Egg.*

Artificial parthenogenesis of the eggs of certain invertebrates can be induced by treatment with isotonic solutions of calcium chloride when the hydrogen ion concentration is approximately the same as that of sea-water. Potassium chloride is, under the same conditions, relatively ineffective in causing parthenogenesis owing to inhibition of the process of maturation. Mixtures of potassium and calcium chlorides may be very effective parthenogenetic agents. The discrepancy between these results and those of R. S. Lillie, and the relation of the process of maturation to the initiation of development is discussed.

Miss D. Strangeways.—*A Comparative Study of Leucocytes and Fibroblasts cultivated in vitro.*

The question of the origin of fibroblasts is of importance in connection with the study of tissue repair. Many workers hold that under certain conditions the non-granular leucocytes of the blood and lymph may become transformed into typical fibroblasts, and state that this transformation is readily observed when the leucocytes are cultivated *in vitro.* As a result of the investigations recorded in this communication, however, it would seem that much of the evidence cited in support of the above view is open to serious criticism. *In vitro* cultures of leucocytes from the peritoneal exudate and of normal fibroblasts have been studied in the living condition by means of dark-ground illumination, and the effects of various fixatives upon the appearance of the two types of cell have also been investigated. As a result of these observations it has been found that transformed leucocytes differ from the fibroblasts (*a*) in their smaller nucleo-plasmic ratio, (*b*) in certain important cytological features, and (*c*) in the character of their intra-cellular and amœboid movements.

AFTERNOON.

Joint Meeting with Sections I and K for communications on Experimental Biology :—

Prof. J. H. PRIESTLEY.—*Factors affecting Cell Growth.*

In the flowering plant, growth, as represented by increase in cell size and subsequent cell division, takes place in very different ways in different regions of the plant. Two main types of cell multiplication can be distinguished, one characteristic of the apical meristem, the other characteristic of the region of shoot or root just behind the apical meristem. These two types of cell growth are defined and the internal factors contributing to their maintenance discussed. In the intercalary meristems, vascular cambium and cork phellogen, both types of cell growth, can also be recognised. Thus in cork formation different types of cell growth are characteristic of Monocotyledon and Dicotyledon, and in the vascular cambium ray initials and fusiform initials show different characteristics.

The organisation of growth in the shoot is considerably elucidated by a clear recognition of these different types of cell growth. Vascular differentiation, in relation to cell growth, supplies the key to the 'articulate' development which is its characteristic feature.

Dr. W. H. PEARSALL.—*The Absorption of Methylene Blue and Orange G. by Plant Tissue in relation to the H. ion Concentration.*

Absorption of an acid and a basic dye by potato tissue varies with the H ion concentration. In the region of pH 6·5 the basic dye (methylene blue) is strongly absorbed and the acid dye (Orange G) is very weakly absorbed. About pH 3·0 the basic dye absorption is greatly reduced and acid dye absorption greatly increased. The increase in acid dye absorption is constantly about 1·5 times greater than the reduction in basic dye absorption. Since these variations in dye absorption are shown both by living and by dead (etherised) tissue, it is assumed that they are due to combination of the dyes with substances having ampholytic properties. Analysis shows that these substances would be iso-electric about pH 4·2–4·5, a figure reasonably near to the iso-electric point (pH 4·3–4·4) of the principal potato protein.

Dr. O. W. TIEGS.—*The Double Helicoid Structure of Muscle.*

The occurrence of striations (discs) in muscle fibres is inferred from the fact that in thin microtome or optical sections they present the appearance of successive transverse lines. Now unless the section be taken along its axis a helicoid or double helicoid will present a similar appearance. It is found in reality that if the focus be taken precisely along the axis of a muscle fibre a double helicoid arrangement of the striæ can be detected.

Prof. A. J. CLARK.—*The Oxygen Consumption of the Frog's Heart.*

The conclusions reported are based on a series of experiments carried out by Dr. A. C. White and the author.

Three methods were used. In methods 1 and 2 we measured the oxygen removed from air in contact with hearts perfused with Ringer's solution ; in the first method the whole heart was used, and in the second the ventricle alone. In the third method we measured the oxygen removed from a suspension of red blood corpuscles in Ringer's fluid placed in the ventricle. The three methods gave concordant results.

We found, in agreement with Starling and Visscher's work on the dog's heart-lung preparation, that the oxygen consumption depended on the diastolic volume of the ventricle, and that it was not increased by increasing the resistance against which the ventricle contracted. Prolonged perfusion with Ringer's fluid reduced the oxygen consumption to about one half the original value, and also reduced the mechanical response, but the addition of serum or of soaps restored both factors to their original value.

The resting oxygen consumption of the heart was from 20 to 30 per cent. of that occurring during moderate activity. Removal of calcium, excess of potassium,

acidity, and addition of narcotics, in concentrations sufficient to arrest the heart's movements, did not reduce the oxygen consumption below the normal resting value.

The resting metabolism of the heart appeared to be much more resistant to the action of drugs than was the metabolism associated with contraction

The drugs mentioned were found to depress in an equal degree the oxygen consumption associated with contraction, and the mechanical response of the heart.

We did not find any certain exception to the general rule that the mechanical response of the heart is proportional to the extent of the chemical change associated with contraction.

Prof. B. A. McSwiney and Mr. R. E. Tunbridge.—*The Viscosity of Smooth Muscle.*

The alterations brought about by electrical stimulation, pH, and drugs in the viscous properties of mammalian smooth muscle, chiefly strips from fundus of cat and rabbit, have been studied by methods similar to those described by Gasser and Hill.

Electrical stimulation, pilocarpine, histamine, acetyl choline, and barium increase the viscosity of the muscular strip. Under certain conditions, atropine abolishes any increase in viscosity due to pilocarpine.

The effect of pH is very slight within the range pH 6.0–8.4. Such changes as occur are in the same direction as are the alterations in length within this range described by Newton and McSwiney. Lowering the hydrogen ion concentration to within the neighbourhood of pH 5.0 causes a small but definite increase in the viscosity of the muscular strip. Extreme alterations of pH, such as $<$ pH 2.0 or $>$ pH 10.0, cause a marked diminution of both the elastic and viscous properties of the muscle.

The alteration in viscosity obtained on addition of pilocarpine and electrical stimulation and atropine depends upon the degree of tension which the muscle is allowed to develop; on the other hand, the increase of viscosity with barium chloride and histamine is dependent upon the amount of drug added.

Monday, September 10.

Prof. J. W. Mavor.—*On Studies of the Effects of X-rays on Heredity.*

Prof. W. C. M'Intosh.—*Abnormal Teeth in the Rabbit.*

Messrs. E. Heron-Allen, F.R.S., and Arthur Garland.—*On the Pegididæ, a New Family of Foraminifera linking up the Globigerinidæ and the Rotalidæ.*

In 1826 d'Orbigny recorded in his *Tableau Méthodique* a Foraminifer from Mauritius, to which he gave the *nomen nudum*, *Rotalia dubia*; no description nor figure was published, and the type specimen remained ignored in Paris until, in 1914, we had occasion to examine the d'Orbigny collections. About the same time we rediscovered the organism in dredgings off Portuguese East Africa, but in the absence of sufficient material we decided not to publish the matter. Since then we have discovered other allied forms and have found it necessary to establish a new Family for their reception.

The *Pegididæ* are perforate Foraminifera of wide distribution, but of very rare occurrence. They are characterised by abnormally thick-walled tests enclosing a few chambers only, set in opposition to each other. The aperture is distinctive and unlike anything hitherto known, sometimes occupying nearly a quarter of the whole surface area of the shell, and presenting very highly specialised features. The *Pegididæ* appear to occupy a position between the *Globigerinidæ* and *Rotalidæ*, having features common to both but no very evident relationship. They inhabit the troubled water on the edge of coral reefs, and they may represent an attempt at the evolution of a type capable of existing under conditions unfavourable to most hyaline Foraminifera.

Mr. J. F. G. Wheeler.—*Changes in the Condition of the Blubber of Blue and Fin Whales.*

Averages of measurements of the blubber for metre length-differences for each species and sex obtained during four seasons' work at whaling stations show a small general increase in blubber thickness with increase in length of whale.

By expressing thickness of blubber as a percentage of the total length of the whale, comparison has been made between the average thickness of all whales of the same species and sex month by month, showing that for Blue and Fin males and non-pregnant females there is an increase in thickness as the season advances at South Georgia and a decrease at Saldanha Bay, South Africa.

Pregnant females are always fatter than normal. They also appear to get fatter at the end of the South Georgia season. Lactating females captured early in the season (June) at South Africa are extremely fat; but when they appear at South Georgia in the second half of the season they are very much thinner than normal.

The records throw some light on the migrations of mature and immature whales, on the time of birth, and the duration of lactation.

Prof. F. Balfour Browne.—*On the Habits of certain Social Caterpillars.*

Social insects are those in which the members of the family do something for the common good, and gregarious caterpillars which spin silk come within this definition.

There are three main types of web spun by social caterpillars, the 'Carpet-web,' spread over the food and eaten with the food, the 'Feeding-web,' spread over the food, the caterpillars living inside it and expanding it as the food is eaten, and the 'Home-web,' from which the caterpillars go out to feed.

Two examples of British 'Home-web' builders are the Lackey Moth caterpillar (*Clisiocampa neustria*) and the Little Eggar Moth caterpillar (*Eriogaster lanestris*). The former species is in an elementary stage, the primary web being quickly deserted, the family breaking up into smaller batches, each batch forming a secondary web and the batches later breaking up into solitary individuals.

The Eggar, on the other hand, is much more advanced, and experiments show that the original home is retained even under adverse circumstances, and that, in the absence of the original home, the family tends to remain together and adopt a secondary centre. The general characters of the Eggar web, the method of construction and its uses, are of some interest; the web seems to be essential for the well-being of the species. The migratory instincts of the full-grown caterpillars are remarkable.

Mr. J. T. Cunningham.—*Objections to the Mutation Theory of Evolution.*

Inherited characters must be determined by the constitution of the chromosomes of the reproductive cells or gametes. Hereditary changes in these characters must be due to changes in the constitution of the chromosomes. According to T. H. Morgan's theory, the characters are determined by particles of the chromosomes arranged in linear series. A new character or mutation, such as double wings in a culture of Drosophila, is the effect of a spontaneous change in the corresponding gene. But in order to explain evolution it is necessary to consider (*a*) the course of the development of the final character, (*b*) the relation of the character to function, *i.e.* to the external environment. According to Morgan's views, all such matters are adequately explained by natural selection, and it is assumed that the external environment plays no part in causing hereditary mutations in particular directions.

It may be admitted that the conception of mutation harmonises well with our knowledge of characters which develop directly and which have no known function or utility, but it is impossible to accept the process of selection as sufficient explanation of the relation between the structure and functions of the animal and the matter and energy of its surroundings. This is especially evident in the phenomena of metamorphosis and recapitulation, and in those of sex-limited characters. In these cases the processes of development are influenced and controlled by internal secretions. It is difficult to believe that the transition during the life of the individual from aquatic to atmospheric respiration in Vertebrates was due to the mere selection of mutations unrelated to the respiratory medium, and still more difficult to understand how the theory of mutation and selection can account for the influence of the thyroid secretion on this metamorphosis. It is equally difficult to believe that the relations of sex-limited characters such as the antlers of stags to the external function of weapons of sexual combat, and to the internal influence of the hormones produced by the sexual organs, have no other explanation than that of selection of mutations in their origin undetermined by these external and internal relations. Morgan's suggestion that the antlers of stags could be explained as a mere by-product of the

testicular hormone is physiologically unsound, and the mutation theory furnishes no reason why somatic sexual characters should be influenced by the metabolism of the sexual organs any more than other somatic structures.

The recent progress of biological knowledge tends to confirm the conception of the adaptive evolution of animals as the expression and result of reactions to the stimuli of the environment, and to justify the conclusion that the genes of the gametes are sooner or later influenced by the modifications of the soma.

AFTERNOON.

Joint Discussion with Section K (*q.v.*) on *A Biological Investigation of British Fresh Waters.*

Tuesday, September 11.

Dr. G. P. BIDDER.—*The Interpretation of the Embryology of Sponges.*

The free-swimming larvæ of sponges do not recapitulate any adult ancestral form, their characteristics are due to special adaptations for distribution and to precocious segregation of tissues. There are, however, two colonial Protozoan forms of whose recapitulation there is possibly evidence. (1) There are signs of a free-swimming ancestor which we may call a 'corona,' an eight-celled circle of flagellates resembling the eight-celled protomastigine *Bicoeca socialis* Lauterborn and the sixteen-celled chrysomonad *Cyclonexis.* (2) The 'corona' may have been succeeded by the 'cylindrus,' an open cylindrical tube of 128 or more flagellate cells. These two forms are repeated without apparent embryological advantage in the ontogenies of the sponges and of their descendants.

Embryology and physiology alike indicate that in the ancestral flagellate colony multiplication of cells was by longitudinal fission alone, as in almost all existing flagellates. For the cylindrus we may deduce also a habit of migration of cells to the interior of the tube, resulting first in the formation of a double layer of cells, clothing the cylinder with flagella outside and inside. Secondly, some of the cells permanently lost their flagella and the colony became truly Parazoan, consisting of two different classes of cells.

Sex has been developed strongly in certain classes of the sponges, but in others the advantages of sex appear to be only attained through the chance, but frequent, fusion of growing colonies. Sex would therefore appear to have been very imperfectly attained in the colonial flagellate ancestor. With sex originated the bilateralism so characteristic of Metazoa.

Dr. S. L. HORA.—*Animal Ecology of Torrential Streams with special reference to Structural Adaptations.*

There appears to be a growing feeling at the present day that evolution is predetermined and that adaptation 'is a chance relationship, not a progressive modification towards particular habitat requirements.' This is due to a misapprehension. Adaptation signifies correlation of an animal with its habitat and, therefore, for the understanding of this phenomenon a superficial knowledge of animal ecology is not enough. Attempt has been made to classify the unlimited gradations in the environment of the torrential fauna. By referring to the two types of *Megalophrys* tadpoles and to the gradual modification and evolution of the Sisorid and the Homalopterid fishes it is indicated that evolution is no more than adaptation of organisms to environment. Attention is directed to the different body-forms of brook-inhabitants, to the devices for increasing specific gravity and to the similar mechanisms for producing differential pressure, and it is concluded that similar modifications are directed towards the achievement of similar ends (convergence). The significance of the principles of 'Opportunity Dispersal' and of 'Change of Functions' is discussed, and it is concluded that evolution proceeds by a continuous adjustment—progressive or retrogressive—of the existing material and that the adaptive structures do not arise *de novo.*

Prof. J. Graham Kerr, F.R.S.—*Spirula.*

As is well known, this very rare and, so far as its shell is concerned, comparatively archaic Siphonopod has for the first time been obtained in considerable numbers by the Danish 'Dana' Expedition, and Prof. Johannes Schmidt has for the first time been able to make observations on its behaviour when alive. The investigation of its anatomy has added a considerable amount of detail to what has already been known, and has provided the occasion for the further discussion of various important general problems of Siphonopod morphology. Amongst these is the evolutionary relationship of the three types of chambered shell—straight, exogastrically coiled and endogastrically coiled. The shell, originally protective, has become hydrostatic in the Siphonopoda. In *Nautilus* the terminal chamber of the shell is ballasted by its being occupied by the body, while the others are occupied by gas. In the evolutionary series leading up to the present-day *Spirula* the shell has become internal and the terminal chamber greatly reduced, and in this way a condition of unstable equilibrium is induced. In archaic fish with the *Polypterus* type of lung a similar unstable condition occurs, but this has been corrected in the evolution of modern fishes with their symmetrical air bladder by the air-containing organ having become rotated within the body into a dorsal and stable position. It would appear that the endogastric position of the shell in *Spirula*, &c., is due to a similar rotation of the shell, after it has become internal, into the position of stability. The straight type of chambered shell is regarded not as primitive within the group Siphonopoda but as being subsequent to the enclosure of the shell within the body, a further development of the tendency already shown in *Spirula*, where the spiral curvature practically disappears during the later stages of shell formation.

Prof. R. Broom, F.R.S.—*On the Evolution of the Mammalian Vomer.*

Discussion on *Bothriocidaris and the Ancestry of Echinoids.* (Prof. Th. Mortensen, Dr. F. A. Bather, F.R.S., and others.)

Afternoon.

Dr. G. S. Carter.—Lantern Lecture on *The Conditions of Life in the Swamps of the Tropics: an Investigation of the Swamps of the Paraguayan Chaco.*

The swamps, which were investigated during a visit to Paraguay in 1926 and 1927 by the author and Mr. L. C. Beadle, lie in the eastern part of the Gran Chaco, the flat country stretching from the Rio Paraguay towards the Andes. The part of this country in which the observations were made is in the latitude of the southern tropic and seventy miles to the west of the Rio Paraguay. The swamps are shallow, contain much vegetation and frequently dry in the cooler months which are here the drier season. Observations of the temperature, pH, bicarbonate-, carbon dioxide-, phosphate- and oxygen-contents of the water were taken continuously during the period October 1926–May 1927 at selected points in the swamps. The penetration of ultra-violet light into the water was also studied. These observations showed that the shortage of free oxygen in the water was very marked and was probably of the conditions studied that of most importance to the life of the fauna. The observations were supported by others made in pools and other waters different in character from the swamps. In these there was never so great a shortage of dissolved oxygen, and at midday the water was often supersaturated with the gas owing to the photosynthesis of phytoplankton.

The truly aquatic fauna and flora of the swamp were scanty and contrasted in this respect with those of the pools. In the swamp the amount of animal life varied with the amount of free oxygen present but not with the variations of any of the other conditions studied. Many of the forms living in the swamp showed adaptations to life in a medium poor in free oxygen. Especially was this the case among the fishes, many of those occurring in the swamps being adapted to the breathing of atmospheric air. *Lepidosiren paradoxa*, *Symbranchus marmoratus*, *Erythrinus unitaeniatus*, *Calichthys spp.*, *Ancistrus anisitsi*, and *Hypopomus brevirostris* are all adapted to this

end in different ways, and all occur in these swamps. In the cases of most of these fishes the use of atmospheric air for respiration was previously known, but experiments were performed with the object of determining the importance to them of this means of aerating the blood and the structure of the accessory respiratory organs was investigated. Adaptations to the same end were also found among the Oligochaetes. Many planktonic forms were found to be able to survive in water of which the oxygen-content was very low (·25–·3 c.c. per litre).

The reasons for the shortage of oxygen in these waters were enquired into, and it is suggested that similar conditions occur widely in shallow tropical fresh waters.

Mr. V. J. Clancey.—*The Cinema in relation to Zoology* (illustrated by cinematograph films).

The value of cinema to zoology lies in that it is a very reliable record of movements in space and time. By virtue of the illusion of perspective, the motion picture gives a good representation of action in three dimensional space—in fact, under certain conditions stereoscopic effects may be obtained on the screen. The time scale may be extended so that the action of one-hundredth or one-thousandth of a second occupies a second or more on the screen, or it may be contracted so that the action of hours or days may be shown in a few seconds.

As an aid to research, cinema supplies a method for the repeated study of a movement or set of movements and for arresting action at any point for further study. The so-called 'slow motion' and 'ultra-speed' films show movements too rapid for ordinary observation, while the 'quick-motion' films show those that are too slow. Cinematography is applicable to all the uses of ordinary photography, such as colour reproduction, photomicrography, and even the use of X-rays and ultra-violet light—for high resolution of unstained tissues.

If suitably edited, films may be used for showing results of experiments to specialised workers, for elementary and technical education, for propaganda and for the instruction of the general public.

(Examples are shown to indicate how these methods have been used in zoology.)

Dr. M. Grabham.—*Food Fishes of Madeira.*

Exhibits.

Sister Monica (Dr. Monica Taylor).—*Methods for the Culture of Amœba and other common Laboratory Animals.*

Miss A. E. Miller.—*The Structure of the Tail of Lepidosiren.*

Mr. R. A. Staig.—*Exhibits from the Bishop Collection of Coleoptera and other Collections of the Hunterian Museum.*

Dr. W. K. Spencer.—*Starfish and Sea Urchins from the Palæozoic Rocks of Scotland.*

See p. [illegible]

Mr. G. E. Hutchinson, Miss Grace E. Pickford, and Miss Johanna F. M. Schuurman.—*Natural History of the Transvaal Pans of South Africa.*

Mr. C. W. Parsons.—*Hearts of Fishes.*

Mr. G. S. Carter.—*The Velar Ciliated Cells of* Aeolidia papillosa. *The young of Lepidosiren. Fishes from the Swamps of the Paraguayan Chaco.*

Prof. L. A. L. King and the Clyde Fauna Committee.—*The Clyde Fauna Catalogue.*

Miss P. M. Jenkin.—*An Apparatus for collecting Freshwater Plankton. (The Jenkin Self-closing Townet.)*

Dr. M. Grabham.—*Food Fishes of Madeira.*

Miss A. Bidder.—*Embryology of* Loligo *and* Sepia.

SECTION E.—GEOGRAPHY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 685.)

Thursday, September 6.

Prof. P. M. Roxby.—*Denmark: a Geographical Study.*

Mr. A. G. Ogilvie.—*The Region of New York City.*

New York gained her pre-eminence among American cities about 1790, and has held it since then because of the geographical position of the city at the entrance to the premier route of the Continent.

Among the geographical factors contributing to the location and growth of New York are: (1) the structure and relief of the section of the Continent between the Atlantic and Lakes Ontario and Erie, and the relation to these of the Hudson-Mohawk valleys; (2) the meeting at the mouth of the Hudson of areas of three distinct rock types; (3) the post-glacial submergence, resulting in the penetration of the land by arms of the sea, and leading to-day to the commercial development of 125 miles of waterfront in the port; (4) an 'east-coast' climate that is not so severe as to close the port in winter and is favourable, as compared with the interior, to the growth of vegetables for city consumption; (5) sources of water supply within a distance of 150 miles, adequate for the present city population; (6) a low tidal range—about 5 ft.—permitting easy access to piers at all stages and, since the flowing tide reaches the city round both ends of Long Island, an excess of ebb over flow which helps to clear out the inland waters contaminated by the city; but this excess is now insufficient for the purpose, and should, perhaps, be augmented by construction of certain tidal gates.

The actual site of New York is unique owing to the peculiar combination of land and water which form it. But the site has some serious inherent defects in that the Hudson River and the ridge of the palisades are real barriers, the daily surmounting of which by passengers and freight costs much in time and money. While the harbour is magnificent, the port has long suffered from lack of elbow room behind the water front, and the existence of the water barriers in turn has resulted in the appalling over-crowding in Manhattan and the fearsome congestion of transit lines.

These conditions have aroused the more far-sighted New Yorkers to the imperative need for the construction of a plan to be followed during the next forty years in the further development of city and the port. The Russell Sage Foundation has financed a regional survey and the preparation of a plan of New York which has been carried out by a committee and a staff under the direction of Mr. Thomas Adams. The volume of their report, which are now appearing, may well form a model for all regional surveyors and planners. For this is the most comprehensive thing of the kind ever attempted. It deals with the whole region in which the citizens live and work, comprising an area of over 5,000 square miles in the States of New York, New Jersey and Connecticut. The plan, which as a whole forms an excellent example of applied geography, economics, sociology and engineering, devises methods by

which the population and industries may be induced to redistribute themselves about a circumference rather than overcrowding along a few radii. It is often forgotten that of the nine million people in the district, nearly 1¼ million are employed in manufacturing. And the factories have grown to a large extent on land that would be better used for other purposes. New land can easily be made for such a purpose by dredging for new harbour accommodation and filling up the marshes west of the palisades and in southern Long Island. There is a project to make such a harbour an industrial area in the future in the marshes of Jamaica Bay, a harbour big enough to include the ports of Liverpool, Hamburg and Rotterdam. In the matter of communications the engineers are equal to the problem. They are already building the first bridge over the Hudson, the greatest suspension bridge in the world, as they have recently built the Holland vehicular tunnels under the river. A great system of belt lines around the city and of radial rail and motor highways will eventually, it is to be hoped, lead to the healthier spread of population over the area, giving ample space in which the city may perform its economic functions more economically and efficiently, and in which the people may lead a life healthier both physically and socially.

Presidential Address by Prof. J. L. Myres on *Ancient Geography in Modern Education.* (See p. 99.)

AFTERNOON.

Prof. Douglas Johnson.—*Physiography of the Atlantic Coast of North America.*

In eastern North America the old pre-Cambrian and Paleozoic rocks of the Appalachian Mountains and Canadian Shield, lifted well above sea-level and deeply dissected by stream erosion, are bordered on the east by a broad band of low-lying sandy coastal plain deposits of much more recent age. In late Tertiary or Pleistocene time a differential warping of the continent carried the northward part downward at least 1,200 feet below its former level, thus permitting the sea to flow clear across the sandy coastal plain belt and come to rest against the older and more deeply dissected rocks to the west. Such is the origin of the two strongly contrasted types of shore-line scenery described in this paper. South of New York the sea still rests against the low coastal plain, giving a simple shore-line characterised by sandy bars, shallow lagoons and broad coastal marshes. North of New York the sea has reached the older rocks, and there is a sudden change to the rocky, irregular coast where bold peninsulas and countless islands alternate with deeply indented branching bays. Here the low coastal plain is found under the sea, forming the famous fishing banks of the continental shelf.

Apparently this major differential submergence towards the north-east is only one of several, perhaps many, oscillations of level which affected this coast in recent geological times. Elevated terraces, bars and beaches are found at various levels up to 400 or 500 feet, occasionally to 800 feet and more according to some observers. These ancient strands are usually inclined, and some of them have been traced as they descend below sea-level. The tilting, however, is not always in harmony with that which carried the coastal plain below sea-level north of New York. Evidently differential movements of the land rather than eustatic shifts of sea-level are responsible for the major features of this coast.

Much interest attaches to the question as to whether the most recent movement was one of emergence or submergence. Daly has inferred a recent eustatic shift of sea-level permitting a land emergence of approximately 20 feet. The physiography of the North Atlantic coast does not support this theory. Evidence is presented to show that the last movement was one of submergence.

The widely held theory that this submergence is still in progress is discussed. Evidence for and against the theory is analysed, and it is concluded that the submergence, which may have been due to an eustatic rise of sea-level consequent on deglaciation, ceased several thousand years ago.

Attention is directed to the rôle of a fluctuating 'high tide surface' in causing fictitious indications of emergence and submergence, and it is argued that mean sea-level likewise is not only an irregular surface but one sensitive to changes in the form

of the shore, rising and falling with variations in shore outline. The bearing of these facts on the problem of recent coastal submergence is discussed, and tidal studies now in progress in the vicinity of New York to determine the form of mean sea-level are described.

Mr. F. Rennell Rodd.—*The Land of the Tuaregs.*

The Tuareg of the Central Sahara represent the survivors of a people which at one time inhabited the interior of North Africa from the Atlantic Ocean to the Libyan Desert, south of those countries which can properly be called Morocco, Algeria Tunisia and Tripolitania, and north of the negroid zone of Equatoria. The latter belt appears to have extended further north in early historical times; indeed, the further back in time the further north are the negroids found to extend.

Leo Africanus, writing in the first half of the sixteenth century, divided the people of the interior of North Africa into five sections. This people is already described as wearing the *litham* or veil, as the Tuareg do now. The five groups of people who may be accepted as the ancestors of the present Tuareg can be identified. The westernmost are called Sanhaja; they at one time ruled most of the interior of North Africa, and ultimately conquered Fez, there establishing the Almoravid Dynasty, that is, the dynasty of the El Merabatin or holy men, so-called when these Tuareg accepted Islam. The second group was an offshoot of the Sanhaja, and lived east of the latter. Both these groups lost most of their Tuareg peculiarities by admixture with the Moors, consequent upon their own conquest of Fez and the conquest by the latter of the Middle Niger. The third group, called Targa, is to-day represented by the Tuareg of Ahaggar and part of those of Air. The fourth group, called Lemta, are the Azger Tuareg of the Fezzan and some of the Air Tuareg. These Lemta occupied the Air Mountains, coming down the Kawar Road from the Fezzan, settling round Lake Chad for a time, and finally invading Air, peopled by Gober negroids from the S.E. They were driven in the first instance south by the pressure of Arab and other foreign interference in the north, and then east by the Semitic thrust across Equatoria from the Anglo-Egyptian Sudan, Darfur and Wadai. The fifth and last area of Leo, that of the Berdeoa people, can be identified with the Tibesti Mountains, where the name Bardai survives, and the Libyan Desert other than that part around the western oases of Egypt. This area is now inhabited by Tebu, a Kanuri folk, with a very recent Semitic infiltration in Kufra and a less recent Semitic occupation of Dongola and the S. Libyan Desert. The Tuareg formerly here are probably the present Awelimiden tribes now living between the Niger at Gao and the desert west of Agades. The name Awelimiden recalls that of the Blemmyes in the S. Libyan Desert; their migration west from Tibesti is traditionally preserved among them. An indication of the practice of veiling by their men is possibly contained in the description given of the Blemmyes that they had eyes in their chest.

The association of the Tuareg with the Libyan Desert both southern and northern is justified by Egyptian records. Notices of fighting between the people of the Nile Valley and Libyans in the deserts to the west occur as early as the Fifth Dynasty. Leaving these early references out of account, there are in the Eleventh Dynasty circumstantial and detailed accounts of people called Tamahu, whose name suggests Temajegh or Temehaq (according to dialect) the language of the Tuareg, the word itself a female form of Imajegh, the name by which the Tuareg refers to the noble tribes of the races. Besides this there are Nineteenth-Dynasty tomb paintings depicting Temahu, and bearing sufficiently striking resemblances to the drawings of figures associated with the Tuareg and certainly made by them in Air many centuries later, as to justify the identification.

Indications exist that the Libyans generally are not one race but are composed of several stocks. The Tuareg, whose history can be traced back, if their identification with the Blemmyes is correct, to a period in the first millennium B.C., and if the deductions from Egyptian records are well founded, at least to the second millennium B.C., seem to be one of these racial stocks which, for convenience of geographical classification, are called Libyan or, in a linguistic classification, Berbers, but which have little in physiological type in common. The origin of the Tuareg is not the same as that of other Libyan types, and is probably connected with the Eastern Mediterranean, even as perhaps one of the other Libyan types descended from the Cro Magnon man is related to a racial stock associated with Spain, France and Western North Africa.

Friday, September 7.

Col. H. S. L. Winterbotham.—*Recent Expansion in our Colonial Surveys.*

Col. M. N. MacLeod.—*Methods of Revision of Ordnance Survey Maps.*

Capt. M. Hotine.—*Air Surveys.*

Afternoon.

Excursion to Drymen, Aberfoyle, and the Blane Valley.

Saturday, September 8.

Excursion to Arrochar, Crianlarich, and Callander.

Monday, September 10.

Mr. J. Holmes.—*The Clyde Estuary.*

The Clyde Estuary is a region of ships, holiday villages and busy industrial towns. A detailed analysis will be found in a recent article in the *Scottish Geographic Magazine* (vol. xiv. 1927).

In this region there is an excellent opportunity to examine the effect which inorganic causes have on organic results.

The water body of the estuary unites three different and distinct physiographic regions, and brings into close contact three contrasting environments. The Highland desert with its valley and lochhead oases forms abrupt contact with the prosperous industrial lowland.

There is an indigenous development in each area of the region, and also a superimposed activity which latter bears no direct relation to the localised natural resources of the areas themselves.

The superimposed development has come from the eastern industrial area. When this activation reached the estuarine region it took three distinct aspects in direct coincidence with the three distinct physiographic areas which compose the region.

Thus there is an industrial zone in the southern area bordering the deep channel in the river, a residential and dormitory zone in the northern area and holiday villages in the oases of the highland area.

The impulse to increased development in the estuarine region may be likened to a series of economic waves. These have, from time to time within the last fifty years, swept down the river. To-day it is evidenced in the migration of Glasgow bridges down stream, the various schemes for dock construction near Greenock, suggested ferries across the estuary, and, in a recent case, the supply of electricity from Greenock on the south side to Dunoon on the north. The rebound of these waves has taken place at the estuary since the highland zone offered resistance to the changes. Is it not a likely phenomena that the highland zone will supply hydro-electric power to its southern neighbour ? The return wave, however, does not make itself felt as far up-stream as the starting point of the original. The locus of greatest activity, then, is the estuary.

Thus we are led to the conclusion that the estuary is destined to be a great outport for the Midland Valley of Scotland.

Mr. J. S. Thoms.—*The Site of Glasgow.*

A map on a scale of 6″/mile, contoured at intervals of 20 ft., the contours having been plotted from all available spot height and bench mark data, was used as a base for his investigation by the writer. The contours were reinforced at fixed intervals of 100 ft. in order to emphasise the structural alignment of the area.

The map revealed considerable diversification of elevation and contour within the urban area. Elevation was shown to fall off from heights of 350 ft. in the N.E.,

in a south-westerly direction, to water level on the Clyde, while south of the river heights of over 100 ft. were attained in the S.W. of the city. More than half the area was under the 100-ft. contour, above which large-scale extension of settlement is only recent.

The geological formations underlying the city are mostly Carboniferous. These are, for a large part, covered over by vast deposits of boulder clay, deposited by an ice sheet which once occupied the urban area, while raised beach deposits occur, especially on the south side of the river, bordering upon the irregular tract of pebbly alluvium stretching on either side of the river.

The boulder clay has been carved into a large number of drumlins, whose axial directions vary considerably. This lack of definite alignment in the steep and smooth-sided drumlins would be a definite obstacle to the laying of routes and streets, probably accounting, to some extent, for the late occupation of the northern portion of the city. In different localities the raised beaches are well preserved and provide efficient tracks for road construction.

The post-glacial valley of the Kelvin within the Glasgow area is narrow and deep. This narrowness has allowed of the construction of bridges at various points at comparatively small cost, while the depth of water and steep valley sides has made dam construction easy and comparatively inexpensive. The large flour mills at Partick Bridge are examples of mills benefiting in this way.

The beaches formed as the river cut down to succeeding levels in the boulder clay in Kelvingrove are now utilised as promenades in this public park.

As the small outcrop of Teschenite dolerite in the Necropolis area of S.E. Glasgow is the only known igneous rock formation in the city, and as only sedimentary rocks and deposits are known elsewhere, the digging of building foundations, laying of underground cables and drains and the construction of tunnels and railway cuttings is fairly easily carried out at comparatively small cost, even although the walls of tunnels cut in boulder clay have to be reinforced. This is rather important, since the majority of railways leaving the centre of the city in northward and eastward directions must do so underground, for large parts of the way, because of the great irregularity of the topography. The sedimentary nature of underlying rocks allowed the one-time shallow and silted channel of the Clyde to be comparatively easily cleared by dredging and blasting.

Although the Broomielaw is the natural down-river bridge situation on the Clyde, the outcrop of more resistant rocks in the neighbourhood of Rutherglen would in all probability have decided the building of the harbour in its present position.

In the neighbourhood of Jamaica Bridge, the 40-ft. contour, limiting the alluvium, retreats northward, enclosing an extensive level area, which at one time had been formed either as an island in the estuary or by the meandering of the former river, and now provides an ideal site for Glasgow's two great railway termini, the Central and St. Enoch Stations. The smaller streams within the urban area, well supplied with water from the higher boulder clay area, formerly drove numerous mills, which old maps reveal to have been the nuclei around which settlement congregated when the city began to expand. To-day many of these streams have been filled in in parts, or completely so, and now provide routeways for some of our more important thoroughfares.

The advent of the electric tramcar and motor car has seen the rapid expansion of the populated area into the higher and steeper outlying drumlin areas, as these forms of locomotion have reduced the obstacle offered by steep gradients.

The large scale movement of coal and iron ore on the Forth and Clyde and Monkland canals formerly did much to promote settlement in the north of the city. However, as these canals have to meander along a course three times the direct distances, their importance rapidly declined with the advent of the railway, and with the partial exhaustion of the Blackband Ironstone in the Carron district.

The encroachment of settlement upon the higher drumlin area to the north of the city is solely due to the great demand for dwelling houses. This is essentially a residential area, as steep gradients and inability to get a strong head of water excludes industry from these hills. Numerous Carboniferous formation outcrops supply the city with abundant building stone, while the situation of pumping stations at high elevations at Possilpark and Riddrie give the low-lying, densely populated part of the city a copious siphon supply of water.

In spite of the fact that the N.W. to S.E. trend of the contours gives the city an aspect essentially towards the river, the tendency to separate residential quarter from

commercial quarter in modern times has been responsible for the withdrawal of the populace to higher, healthier and more diversified areas away from the river, leaving warehouses and business establishments in possession of the level, low-lying alluvial tracts.

Mr. A. W. McPherson.—*The Water Supply of the Glasgow District.*

In this paper it was remarked that since early times the question of water supply had been one of pre-eminent importance—not surprising when one remembers that roughly 80 per cent. of the human frame is composed of water.

This discussion involved the consideration of several factors closely inter-related.

1. *Topography.*—The proximity of high land masses greatly facilitates the conduction of water by gravitation—in this respect the Glasgow district is eminently suited, being almost entirely surrounded by upland areas. Passing from south to north these are: the Renfrewshire Uplands, separated from the Kilpatrick Hills and from the Campsie Fells by the valley of the Clyde, which is very narrow at this point. Further north there is the western extension of the great Valley of Strathmore, north of which lies the mountainous region at the south-western end of the Grampians.

2. *Geology.*—This is important, for the nature of the rocks often seriously impairs the quality of water available.

The volcanic masses of the Renfrewshire Uplands and of the Campsie Fells and Kilpatrick Hills are separated by the Carboniferous rocks of the Lanarkshire coalfield area, which is narrow at Glasgow, but widens out towards the east. The Valley of Strathmore is based almost entirely on the Old Red Sandstones, north of which, and separated from them by the Highland Boundary Fault, is a region of durable and almost impermeable Primary rocks.

Thus the prevailing rocks of these upland masses being either igneous or of primary formation, the water given off is very soft and free from mineral impregnation—largely accounting for the early establishment of bleaching mills at the fringes along the break of slope.

3. *Rainfall* is closely related to topography, as was seen from the map constructed by the speaker. Rainfall increased with altitude, *e.g.* over 60 ins. on the Campsies and over 110 ins. in the N.W. corner of the Loch Katrine Reception Area. On the plain the rainfall was found to decrease with passage eastwards from about 50 ins. at Dumbarton to less than 35 ins. in the eastern part of Glasgow.

In such a region it is obvious that the factors of evaporation and permeability are negligible.

Therefore the Glasgow area is a region eminently suited for an abundant supply of good water by gravitation, yet it was not until the latter part of last century that this occurred. Before the present mode of supply was developed two eras are recognisable:—

1. The 'Well era' up till 1806, in which the water supply was obtained from a number of wells (over thirty) which yielded very unsatisfactory water of doubtful quality and origin.

2. The 'Water Company Era,' 1806-1859, in which the water supply was obtained from the Clyde and passed through very crude filters to the town reservoir. The water grew progressively unwholesome with the increasing sewage discharge into the river from the rapidly developing coalfield area further upstream.

Numerous alternative schemes of supply were suggested, only one of which materialised—the Gorbals Water Company—utilising the headwaters of the Brock Burn. This scheme is still in existence, and serves the useful purpose of supplying places at high elevations, or at distances from Glasgow to which it would be both difficult and expensive to send Loch Katrine water.

The attention of all investigators was directed to the area north of Glasgow because of—

1. Suitable elevation close at hand.
2. Very soft water.
3. Little moss or cultivated land, therefore a low content of organic matter.
4. No mines, therefore no apprehension of damage to the works through subsidence.

The Loch Katrine scheme was preferred to Loch Lubnaig because—

1. It is higher—thus facilitating the conduction of water over the intervening valleys and ridges.

2. Only two valleys to cross, whereas in Loch Lubnaig scheme four valleys had to be crossed.

3. The ease of damming up the natural outlet of Loch Katrine.

The speaker constructed a hypsographic curve which showed that 55·6 per cent. of the land in the Loch Katrine Reception Area was over 1,000 ft., thus yielding a drainage area of high elevation. It may be noted, for comparison, that in the World Curve only a very small percentage is over 1,000 ft.

There followed a brief outline of the stage of development of the Loch Katrine scheme which was completed in 1859. It was shown how, on account of ever-increasing demand with reference to a graph of population, the storage capacity was increased from 5,600 million gallons to approximately 9,800 million gallons in 1885, and increasing the available supply from 50 to 110 million gallons per day, involving the duplication of the aqueduct and service reservoir at Milngavie. It was shown that these storage reservoirs contained a total capacity of 1,200 million gallons, yielding eighteen days' supply at the daily consumption of 67 million gallons.

It was pointed out that the Compensation Water to the Teith came from a reception area (Lochs Vennacher and Drunkie) entirely distinct from that which supplied the city. It was shown also how this compensation water as a fraction of the total available to the city was much higher than in many parts of England and Wales. The soft quality of the water had led to the establishment in the city and district of fabric and other industries dependent on soft water in contrast to the usual *regime* of establishment at or near the source of such water.

A graph was described showing the relative importance of the consumption of water for domestic and for trade purposes. The provision for future demand by raising the level of the loch, increasing the storage capacity to 14,200 million gallons and by utilising the water of Glenfinlas (if necessary) was found to be sufficient, yielding a total of 132 million gallons per day or approximately twice present-day demand of 77 million gallons per day—truly a wonderful provision for future demand.

Mr. P. R. Crowe.—*The Geographical Position of the Scottish Coal and Iron Industries.*

The object of this paper is to explain the maps on view. Before doing this we can state, with regard to the Scottish coalfields, that—

1. The coal occurs in definite basins.
2. Carboniferous volcanic activity was very great.
3. The interbedded 'dayband' and 'blackband' ores of iron played an important part in the past.
4. The coalfields are easily accessible.

The detailed structure of the fields is intensely complicated and mining difficult, especially in some areas. But limits are definite, being defined by the outcrop of rocks older than coal. The rough coincidence of coalfield working with basins of river drainage is a feature by no means common in other parts of the world.

Carboniferous volcanic activity has been a great influence. There were lava flows which built up the broad plateaux of which the Ochils, Campsies and Renfrewshire Hills are remnants. Also beds of ash and scoria were deposited amidst the coal seams. Finally, numerous late intrusions of all kinds have been mapped—they have buried, baked or destroyed the coal in various areas. If they occur on the surface they are marked by sharp crags or rocky bosses.

The 'dayband' and 'blackband' iron ores—easily worked along with the coal—gave an enormous fillip to mining, and for twenty years, between 1843 and 1863, Scotland produced over a quarter of the pig iron of the United Kingdom. Output of these ores reached a maximum of over 2½ million tons per annum between 1875 and 1880. It then fell rapidly before the competition of imported ores, and in 1927 was a mere incidental, mined with coal or fireclay—28,300 tons. But modern blast-furnace installations are still to be found in close proximity to the old ironfields.

Finally, the accessibility of the fields scarcely needs further emphasis. Conditions in Scotland were favourable for early settlement, for early industry and for early export.

The Carboniferous Limestone series is best developed in the east—it is here some 2,000 ft. thick—as compared with 500 ft. in Ayrshire—it actually has some important limestone beds, and also contains coal amounting to 50 ft. in twelve seams in the Lochgelly area, and to 95 ft. in thirty-four seams in Midlothian. Millstone Grit

finds its widest extension and greatest economic importance in central areas, *e.g.* at Glenboig. The Coal Measures proper, finally, are thickest and richest in the east, but are more completely preserved in the west, central and western areas, where they lie buried under Barren Red Measures and later rocks to form a little concealed coalfield round Manchline. In this area, however, volcanic activity seems to have ruined the coal that erosion spared.

We will attempt to point out a few facts with regard to the various fields—it required fifteen volumes of the Geological Survey to describe them.

The Ayrshire coalfield is relatively insignificant to-day, despite its area. There are two main sections—the Irvine basin north of Troon, the Ayr basin to the south. The northern basin has long been worked by numerous small old-fashioned pits along the river. Export via Irvine and Ardrossan was once quite important. In the southern basin mines are few and scattered.

The Central Field may best be considered as a wide trough extending from Hamilton to Alloa, from Clyde to Forth and mined to-day chiefly at its extremities and along either flank. It is abruptly truncated in the S.W. by the Sechmont fault and in the N.E. by the Ochil fault. There are at least three subdivisions.

Firstly the Hamilton or S.W. section with large modern deep pits—situated along the Clyde 'Laughlands' and on the neighbouring slopes. Secondly the central section extending from Airdrie to Falkirk and from Kilsyth and Kirkintilloch to Bathgate and Shotts. This area is more complex—more interesting structurally and historically. At one time this was the scene of great activity. Much of the field has been ruined by intrusive sills so that large modern pits are only to be found towards Kilsyth and Bathgate.

The eastern pits in Fife and Midlothian are characterised by their modern equipment and great size. The area is one mainly of coal mining and coal export, manufactures being a secondary consideration. The Lothian field was the only one to show an increase in output between 1913 and 1927. Two dislocations should be noticed with regard to future developments—the Sheriffhall and Pentland Faults.

In contrast to the general simplicity of this area the W. Fife or Lochgelly-Cowdenbeath field is very complicated—there are large masses of intruded material. Here export was always the chief concern.

The Douglas and Sanquhar fields are of local significance only.

Methil, Burntisland, Leith, Grangemouth, Glasgow and Ayr, of course, stand predominant in the coal export trade. We have to note: the general decline in shipments—attempt of the large ports to make up for declining exports by an increased export trade—the growing coal trade of Ayr.

Maps to show the location of rolling mills, foundries, railway works and oil shale distilleries, &c., would be valuable. There has been time only for one, showing distribution of blast-furnaces, in and out of blast early in the year. Location depended on local ore supplies—but imported ores now predominate and necessitated reorganisation.

In conclusion: much that is of interest in connection with the iron and coal of Scotland is reflected in Population Maps described by me in the spring number of the *Scottish Geographical Magazine*, 1927.

Prof. O. Holtedahl.—*Land Forms in some Antarctic and sub-Antarctic Islands.*

Afternoon.

Discussion on *The Teaching of Geography in Scottish Schools.* (See p. 639.)

Tuesday, September 11.

Dr. C. B. Fawcett.—*Recent Developments in the Regions adjacent to the Tees Estuary.*

Dr. A. Geddes.—*Soil and Civilisation in Bengal.*

The great alluvial rice plain of Bengal is well defined by the edges of the jungles of the hills to north, east and west, and those of the tidal marshes to south. (Its unity of speech, the Aryan Bengali, is a sign of considerable unity of culture.) There is, nevertheless, a difference in water supply from E. to W., the effects of the heavier

rainfall of the east being greatly increased by the eastward movement of the Ganges waters since historic times. One possible explanation of this is that the deforestation of the drier western jungle slopes began early, their consequent denudation causing deposit of coarse silt in the beds of the historic Ganges and its system, choking these.

The result is a profound alteration in conditions of water and soil—of seasonal inundation, water table and deposit, or non-deposit, of fertilising silt. From this follow contrasts in agriculture and subsistence, in health, in density and in increase or decadence of population—Eastern Bengal dense and increasing, Western Bengal sparser and stationary. The last contrast of the two regions lies in their levels of culture and ability, for the historic intellectual supremacy of the West is giving place to that of the East.

This rough comparison of Eastern and Western Bengal may be pursued further, and demands detailed mapping of the physiography, soil and water conditions to-day. These are suggestive in indicating conditions in various regions in the past, and hence in suggesting, for example, the explanation of the early rise of the Barind (N. Bengal) and its later decadence. Similarly for the distribution of higher castes, of culture and education continuously from early times along both banks of the western branch of the Ganges (*i.e.* the Bhagirathi) and westwards from it.

Besides the rural changes of physical conditions, those of craftsmanship and industry in the cities are significant, economically and also culturally. The finest muslin weaving, of Dacca and East Bengal, has been replaced by the coarsest of textiles, jute.

Mr. W. Fitzgerald.—*The Population Problem of South Africa.*

South Africa provides the supreme instance of a society and State of European composition established in the Negro zone. Colour problems here are of unrivalled difficulty, and their solution, satisfactory to the welfare of all the ethnic groups concerned, is regarded as unattainable. The ideal of the Dutch and British is to maintain a State on the European model: neither is willing to concede to the Blacks, who form more than 80 per cent. of the population of the sub-continent, an active share in the building of this State. Although Europeans established settlement nearly three hundred years ago, their ideal of a White State is the conception of the last few decades only.

Elements in the Population of South Africa and their Distribution.

(*a*) *Whites.*—British strongholds are the coast towns, Natal and the Rand. The Dutch are the dominant element in the rural population, which is sparse throughout. The gold-bearing Rand increases in density of population faster than any other district: the increase is largely at the expense of the countryside.

(*b*) *Bantus.*—Distributed mainly towards the east, where grasslands are richer; particularly dense in Natal (where they outnumber the Whites by 9 to 1) and the Eastern Cape Province.

(*c*) *Asiatics.*—Chiefly Indians in Natal (where equal to White population) and the Rand, but including the Cape Malays. Indians admitted after 1860 for the cultivation of the Natal plantations. Though without social or political opportunity, they offer severe competition to Whites of the trading class.

(*d*) *Cape Coloured.*—A half-caste stock limited to the Cape Province (40 per cent. of the population of Cape Town), which is becoming assertive of its rights and is demanding an effective share in political representation.

Character of White Colonisation.

South Africa, outside the Low Veld and the coastal plain of Natal, provides a friendly climate, though the sub-tropical sun and high altitude (Johannesburg nearly 6,000 feet from sea-level) are not without certain ill-effects: the ‘ Poor White ’ class, product of racial decay, may owe its condition to the cumulative effect of climatic influence over many generations.

Percentage increase of White population, by natural increase alone, now equals that of the Bantus. But colonisation is only partial. The South African farmer differs from the Australian and Canadian in his complete dependence on cheap coloured labour. South Africa is never likely to be a ‘ field ’ for the immigration of European land-workers while all unskilled labour is classified, in the code of the country, as ‘ Kaffir work.’ White South Africa is an aristocracy erected over a great population

of semi-serfs who possess no political power and are never likely to secure by peaceful methods social equality with the Whites.

The two big groupings in the Black society are (*a*) the tribalised Bantus, (*b*) the urban Bantus who have been persuaded to abandon the tribal environment; Kaffirs working on European farms go along with this group. There is a tendency for (*b*) to increase in numbers at the expense of (*a*), and this with White encouragement.

The rise by the Bantus from unskilled to skilled trades is an inevitable development. 'Colour Bar' legislation can but temporarily check the operation of economic law. Will it be possible to deny social and political opportunity to the Bantus when the present difference in economic status between Whites and Blacks has been removed?

Without a policy of segregating the Whites and Blacks in two distinct zones, so that each group may be, as far as possible, self-supporting, the ultimate submergence of the White State is assured. The aim of White South Africa should be, far from destroying the tribal basis of Bantu life, to strengthen its influence and to check the flow of Bantu labour into the towns, where its presence aggravates the social, economic and political problems of the State.

The relations of the two White stocks—British and Dutch, still distinct nationalities—provide an insignificant problem, viewed in the right perspective, in comparison with the menace of a conflict of Colour in South Africa.

Afternoon.

Excursion: Cardross to Balloch.

Wednesday, September 12.

Mr. R. A. Pelham.—*A Fourteenth-century MS. Map of Britain and its Influence on Sixteenth-century Cartography.*

This fourteenth-century map hangs in the Bodleian Library. Its author and precise date of construction are unknown, but it may be tentatively ascribed to the second quarter of the century. The map is remarkable for its system of roads and mileages and the tolerably accurate representation of the coastline of England. Scotland is shown in a curiously elongated manner, the section north of the Forth being separated from the rest by a waterway as in the Matthew Paris maps.

The influence upon later maps is based largely upon the representation of Wales. Cardigan Bay is made convex, the Lleyn Peninsula of Carnarvonshire is absent, Puffin Island is grossly exaggerated and a large river (Fluvius Month) is shown flowing into Carnarvon town. Plynlymon is depicted as a lake instead of as a mountain.

Munster's wood-cut map of Britain in his 'Geographia Universalis' of 1540 closely resembles the fourteenth-century map in outline, but shows a greater simplification of topographical detail. The Plynlymon error has been corrected, and a number of other mountains are depicted both in Wales and England. Scotland is only shown as far north as Edinburgh. Several errors have been committed in the transcription of place names from the earlier map, *e.g.* 'Gilford' appears as 'Silford,' 'Lewis' (Lewes) as 'Lewig.'

In the copper-plate map of George Lily, drawn up at Rome in 1546, the coastline of England has been modified, that of Lancashire being markedly straight, and a completely new Scotland is shown, although the errors relating to Wales persist. In addition, Llandovery now appears on the River Usk instead of on the River Towy.

Apparently another influence has been at work, and the new errors can be traced to a MS. map of c. 1540. Here Scotland is shown more crudely than in the Lily map, but much more accurately than in the fourteenth-century one.

A series of maps made during the second half of the sixteenth century and shown by M. C. Andrews to be based upon the Lily map, is as follows:—

1. 1549 Antwerp (Johannem Mollijns).
2. 1555 London (T. Gemini).
3. 1556 Rome?
4. 1556 Venice (Andreas Valvassorus).
5. 1558 Rome (Sebastianus a Regibus Clodiensis).
6. 1562 Venice (Ferrando de Berteli exc. 1561).
7. 1563 Venice (Camocio).
8. 1589 Rome (Marcus Clodius).

Nos. 1 and 4 of the above are wood-cuts, the rest copper-plate.

The influence of the Lily map is also shown in the following maps :—

MS. map included in Battista Agnese's Atlas of c. 1554.

Tabula Nova of British Isles in editions of Ptolemy issued at Venice by Ruscelli and Moletius in 1561, 1562, 1564 and 1574, and also, from the same plates retouched, in Ruscelli's Venice editions of 1598 and 1599.

A map of Britain painted on a wardrobe at Florence in 1570 by Ignazio Danti.

SECTION F.
ECONOMIC SCIENCE AND STATISTICS.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 685.)

Thursday, September 6.

Prof. W. R. Scott.—*Economic Resiliency.*

After a crisis the conditions of trade recovery have probably come into existence before the actual recovery has become apparent. One of these is Resiliency, *i.e.*, the power which endeavours to react against trade depression. The nature of this reaction may be partially illustrated by a remarkable instance of resiliency and recovery in the West of Scotland 1771–1791.

Glasgow has made great progress between 1708 and 1775, through the development of trade with the West Indies and with America. In that period the population had trebled and the rateable value of houses had increased five times. In 1771 the goods manufactured in Glasgow were valued at £452,000. The progress of Scottish trade from 1771 to 1791 was as follows :—

	Imports.	Re-exports.	Home-produced Exports.	Total Exports.	Total Trade.
1771	1,386,329	1,353,861	503,473	1,857,334	3,243,663
1778	682,289	252,183	450,637	702,820	1,358,109
1791	1,941,631	382,328	914,207	1,230,884	3,238,166

Since this trade depended upon the re-export of tobacco, and to a less degree on that of iron goods, it was particularly vulnerable and fell off by more than one-half in 1778. Yet by 1780 the value of home-produced exports had reached the level of 1771, and by 1791 the total trade had nearly regained its former value. How far resiliency and recovery was aided by the Industrial Revolution is discussed.

The necessity for making good losses and recovering trade is the primary condition of resiliency. Its tangible results may be delayed by the need for clearing away the wreckage of the crisis, and also the period of gestation must be allowed for. In the preparatory process leading towards recovery on the mental side the qualities of enterprise, judgment and adaptiveness are important. (1) Enterprise is affected as between individuals and nations by circumstances, some reaching maximum activity under favourable, others under unfavourable, conditions. (2) Before enterprise reaches concrete results, judgment as to the prospects is required. In times of depression such judgment tends to be somewhat pessimistic. Thus of schemes under consideration it is usually those whose prospects are considered most favourable which are first realised; later those where the risk is greater are tried. (3) New conditions appearing at a time of crisis may or may not be permanent—if they are permanent, an important element towards recovery is the degree of adaptability which exists.

Resiliency is significant in social progress. The character of the resiliency with which trade depression is met exerts an influence over the whole of the subsequent trade cycle. It seems probable that a high degree of resiliency is characteristic of a virile people.

Mr. S. Mavor.—'*Suggestion' Schemes as a Means of promoting Individual Co-operation by Workpeople.*

National Councils and committees of representatives of capital and labour meeting in London may do much to improve industrial relations; how much will depend chiefly on the willingness of both sides to sacrifice to the common cause present advantages, real or supposed. When national negotiating bodies have done their best there will remain the real and basic task of giving in the workshops practical expression and effect to the awakened spirit of goodwill and co-operation. In the workshops goodwill was lost: in the workshops alone can it be regained; the initiative is with the employer and it is already being widely exercised. A condition essential to success of effort in this direction is that the firm's relation to its employees shall be inspired by human sympathy and consideration for the interests of the workers, and that all dealings shall be governed by consistent fairness. Where this fundamental condition exists many methods of promoting co-operation of the workers are practised with success; it is here submitted that one of these—Suggestion Schemes—has received less attention than it deserves.

The purpose of a suggestion scheme is to induce workpeople to apply their intelligences to the work in hand, and to suggest how time, effort or material, might be saved in the doing of it. It is probably true to say that the greatest source of waste in the engineering industry is the comparative stagnation of the reservoir of latent mental abilities and mechanical aptitudes of the men in the workshops; the sluices should be opened and streams of ideas should be made available for enhancing the workers' earnings, and for reducing the cost and improving the quality of the products. 'You are not paid for thinking' has been the too-frequent snub by the wrong kind of foremen to men who have had the initiative to put their heads out of their shells. Management does not have a monopoly of brains, and workmen ought to be paid for thinking, and it is worth while so to pay them.

It has been complained on behalf of the workers that under modern workshop conditions they do not have opportunity for self-expression, and that this is a cause of much industrial unrest.

A suggestion scheme provides to the workman wide scope for his legitimate and laudable ambition to exercise his creative abilities, and to stamp his own individuality upon his work; it is a channel through which he can make personal contribution to technical progress, and so have a conscious share and proper pride in promoting the general advance, while reaping immediate and appropriate reward for his effort. The fuller exercise of his faculties is a source of pleasure to a workman; it increases his self-respect and enables him the better to realise his place in the industrial and social structure. Suggestion schemes contain large possibilities of fostering goodwill and practical co-operation of the workpeople, and of promoting industrial harmony; they provide opportunities to the workers of increasing the value of their contribution to industry and of enhancing their earnings by adding the work of their heads to the work of their hands.

Mr. G. C. Allen.—*Changes in Methods of Industrial Organisation in the West Midlands since* 1860.

This paper deals with changes in the type of industry conducted in the West Midlands area, and with changes in the scale, administration, and control.

Friday, September 7.

Prof. Mauritz Bonn.—*Mediæval Economic Theory in Modern Industrial Life.*

Dr. K. G. Fenelon.—*Some Aspects of Road and Rail Transport.*

During the past few years several causes have combined to focus public attention on the position of inland transport in Great Britain. The rapid development of mechanical road transport has brought a number of difficult problems into prominence, while trade depression has had severe reactions on railway finance. Especially acute

is the question 'What is to be the relation of motor road transport to the railways?' It is with this question that the paper is specifically concerned, though incidentally other problems connected therewith are considered. Road transport has proved a severe competitor to the railways in regard to certain types of traffic, though it has also brought traffic to the rail. On balance, however, the railways have been the losers. Mutual recriminations between rail and road operators have complicated the question, *e.g.* the railways assert that 'road transport is a subsidised industry.'

Competition has not furnished a solution to the road and rail problem, and there has been an increasing tendency to search for some compromise whereby the two methods might be co-ordinated to their mutual advantage and to the benefit of the public. Both road and rail transport are essential to the community, since each can render certain services which cannot be so well performed by the other. The economic basis of co-ordination lies in this differentiation of function. In consequence great advantages would result from co-ordination, but owing to the fact that their economic spheres overlap there are many practical difficulties.

Co-ordination might take various forms: (1) co-operation between independent concerns; (2) co-ordination based on the provision of railway-owned road services or on financial control of road concerns by railways; (3) quasi-legal co-ordination. These various methods are examined, and the case for and against the grant of extended road powers to railways is incidentally, though briefly, discussed.

Is co-ordination to the public interest? On the one hand co-ordination would eliminate wasteful competition, but on the other it might lead to monopolistic exploitation of the public, to restriction of facilities or to inefficiency. It is probable that any complete scheme of co-ordination would result in a demand for the setting up of public bodies to control the co-ordinated transport system in the interests of the public.

Monday, September 10.

Presidential Address by Prof. ALLYN YOUNG on *Increasing Returns and Economic Progress.* (See p. 118.)

Joint Discussion with Section J on *The Nature and Present Position of Skill in Industry.* (Prof. T. H. PEAR; Prof. H. CLAY; Mr. C. G. RENOLD.)

Tuesday, September 11.

Joint Discussion with Section M on *The Incidence of Taxation in Agriculture.* (Mr. J. A. VENN; Dr. J. S. KING.)

What are popularly referred to as the 'burdens' on British agriculture are four in number, viz.: tithe, land-tax, rates and income-tax. Peculiar in origin and in their economic characteristics, the two first affect the owners of land. Rates, nominally falling on tenants, are, in varying degree, transferred to landlords, who also contribute the bulk of the income-tax derived from the industry. All have been progressively modified, but tithe and land-tax, although redeemable, are very uneven and arbitrary in incidence. Each Royal Commission appointed during the last century advocated remission of taxation to agriculturists and, accordingly, every period of depression has witnessed Statutory action. In 1896 and in 1923 rates on agricultural land were halved, in 1929 they are to disappear; land-tax has been reduced from a maximum of 4*s.* to 1*s.* in the pound; tithe has been stabilised (perhaps without due consideration of possible future money values) at £105; income-tax grants unique privileges to the occupiers of agricultural holdings. Nevertheless, each generation of farmers, supported by the press, continues to protest against the weight of taxation borne by the industry. Analysis shows, however, that even in the past the position was considerably exaggerated. Rates on agricultural land, which averaged 2*s.* 2*d.* to 2*s.* 6*d.* per acre in the eighties and nineties, still stood at under 3*s.* immediately after the war and little above that figure in 1927–8. The present level is equivalent to £10 per 'farm,' or £13 13*s.* per 'farmer,' and represents less than 2 per cent. of the outgoings on the majority of holdings. Thus it costs from £8 to £10 to produce an acre of cereals, of which 30*s.* to £2 is accounted for by labour, 30*s.* by rent and 2*s.* to 4*s.* by rates. Tithe, if averaged over the farmed area, amounts to 2*s.* 6*d.* per acre, £8 per

'farm,' or £10 17*s.* per 'farmer.' On the same basis land-tax is a charge of 5½*d.* per acre, £1 9*s.* 3*d.* per 'farm,' and £2 per 'farmer.' *Data* relating to the yields under the different schedules of income-tax are lacking, but the *Report* of the Colwyn Committee contained an unofficial estimate of £1,500,000 as the contribution of the United Kingdom 'farming profits' to income-tax in 1922–3, equivalent to a charge (not itself an element in the cost of production) of about 8*d.* an acre. Only a few hundred farmers annually elect to be assessed under Schedule D, the majority of tenants securing total exemption by adhering to Schedule B.

The value of the output of English agriculture has been officially computed at £225,000,000, and the aggregate weight of the four 'burdens,' exclusive of the yield of Schedule A property-tax, cannot represent more than 5 per cent. of this sum, or about 4*s.* in the pound on the gross rental value of the land producing it. While, owing to the uneven incidence of land-tax, and especially of tithe, owner-occupiers of certain properties may find the cumulative weight considerable, the more even incidence of rates is seldom really heavy. Any proposal for the complete abolition of land-tax, perhaps desirable on grounds of equity and of fiscal expedience, always rouses opposition from persons who have redeemed this charge. Tithe has begun to undergo the process of compulsory redemption by means of a sinking fund; rates will shortly only attach to farm dwelling-houses. All statutory reliefs have placed additional charges upon non-agricultural ratepayers and upon the general body of tax-payers. National contributions, direct and indirect, formerly made on grounds of urgency, recently as aids to a 'productive' industry, have grown progressively, and in consequence English agriculturists are, judged by foreign and even colonial standards, lightly taxed. The passage of time has more than counter-balanced certain hardships and anomalies in connection with the taxation of land in bygone centuries, and it seems questionable if further concessions are called for, or even practicable.

Mr. L. C. ROBBINS.—*The Question of Hours in Industry.*

Wednesday, September 12.

(*a*) Major L. URWICK.—*Rationalisation and Industrial Education.*

Meaning of the term 'Rationalisation'—narrower conception implied in the German term—use in this country—wider significance given by the Economic Conference—Rationalisation and Scientific Management.

Importance of an understanding of Modern Management Practices—the difference between classical economics and the Rationalisation conception—scientific management and national efficiency—international co-operation.

Provision for Research and Education in Great Britain—variety of institutions—the attitude of the employer—lack of correct practical contacts—effect on number of students.

The teaching of Management—Commerce and Industry—idea of specialisation—universality of management problems—variety of syllabuses—need for an agreed standard—the examination method—the case method.

Is an agreed standard possible?—a matter for educationalists—how it would appeal to the employer—an institute of Industrial Management.

(*b*) Mr. C. LE MAISTRE.—*Standardisation in Industry.*

Discussion. (Prof. DE PAULA.)

SECTION G.—ENGINEERING.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 686.)

Thursday, September 6.

Mr. J. W. THIERRY.—*The Engineering of the Zuyderzee Works.*

The paper begins with describing the Zuyderzee as a gulf penetrating far into the land; the northern part (Waddenzee) consisting of shoals intersected with deep channels, and the southern part with an even bottom but a small tidal range.

According to the general scheme of the Zuyderzee works, a heavy bank will enclose the southern part of the gulf; of the enclosed area (915,000 acres) four parts (total area 550,000 acres) are to be reclaimed separately. In the centre a fresh-water lake (Yssellake) of 270,000 acres will remain as a storage basin to receive the water of the River Yssel and other tributaries. The lake will discharge into the Waddenzee by twenty-five sluices in two groups; each sluice is 40 feet wide.

When the influence of the enclosing upon the tides in the Waddenzee was investigated it was found that the tidal range would increase in those parts, and that especially storm tides would rise to a higher level than at present (maximum 45 inches at Den Oever, Isle of Wieringen).

Consequently the enclosing dam has to be constructed with a higher crown than was deemed sufficient previously, and the sea banks around the Waddenzee have to be heightened.

The enclosing dam will consist of a boulder clay core with a body of sand covered with clay behind it; the slopes are faced with stone pitching, and the toes are protected from scour by mattresses of brushwork. The height of the crest varies from 20 feet 4 inches to 24 feet 8 inches above Normal Amsterdam Level; on a high berm on the inner side a railway and a road are projected. The dam is being built upon the sea bottom, which has a depth of about 10 feet below L.W., excepting the deeper channels.

The dam, with a total length of 18½ miles, is to be built in such a way that the tidal currents around the head of the work will cause the least possible impediment. The enclosing will be effected gradually in eight years; the final closing will be executed in two places simultaneously, where the deepest channels have to be crossed. To that end artificial bars or sill dams will be constructed in the channels beforehand, to serve as a base for the superstructure of the dam.

The mean velocity of the flow over the sills will increase during the operation. The extent of the increase has been calculated, and the distribution of the velocities over the crown of the sill dams was investigated by experiments on small-scale models. It was found that by taking adequate measures it will be possible to control the velocity and to keep it beneath a dangerous limit.

The banks of the areas to be reclaimed will be constructed on the same principle as the enclosing dam: a core of boulder clay and a main body of sand.

After these banks will have been constructed the water is to be pumped off the embanked areas, and the canals, drains and roads are to be laid out on the dry sea bottom before the soil can be cultivated.

The capacity of the pumping plants will be sufficient to drain off a rainfall of ⅓ inch per twenty-four hours in the same period.

In the N.W. polder (which at present is being embanked) two pumping stations will be erected, with a total capacity of 835 cubic yards per minute.

If no serious contrariety is encountered the enclosure of the Zuyderzee will be accomplished in 1934. The N.W. polder will be embanked in 1929 and the soil will be cultivated in 1934.

The whole of the Zuyderzee works, if progressing favourably, can be finished in 1952.

Joint Discussion with Section L on *School, University, and Practical Training in the Education of the Engineer.* (Sir William Ellis, G.B.E.; Col. Ivor Curtis, C.B.E.; Sir Henry Fowler, K.B.E.; Mr. W. W. Vaughan; Prof. A. L. Mellanby; Prof. Sir James Henderson; Prof. W. Kerr.)

Col. Ivor Curtis.—(1) Modern developments make an increasing call on the engineer of to-day—for wider practical knowledge, more thorough scientific training and better general education. This is not confined to the professionally qualified engineer, but extends down the whole chain of responsible workers.

(2) As an aftermath of the war the country is fighting for its existence as an industrial nation. To live it must design better, produce more cheaply, give better value and sell better than its rivals. Training for production and management has become a vital issue.

(3) With the spread of modern ideas and the development of education a greater flow is to be expected from the bench to positions of professional responsibility and management.

(4) These circumstances together with the decay of the old apprenticeship system, combine to render very necessary a reconsideration of existing systems of education and training.

(5) The fundamental problem :—how to secure that the three essentials—workshop training and experience, technical education, and general self-development—are all obtained during the pre-university stage without the sacrifice of any one of the three to another.

(6) The Air Force system of apprenticeship training considered in this connection. The scheme a large-scale experiment with the new product of the post-primary schools. The underlying ideas of the scheme : the better the general education of a boy of sixteen the quicker can he absorb technical training and acquire skill of hand ; the process can be further quickened if his education is continued at a corresponding level and in the closest touch with his workshop training and everyday experiences ; by bringing the boy and his education into touch with real life he can readily be made a working partner in the process of his own development. The experience gained suggests that with boys of this type and a carefully correlated course the increased rate of progress in the shops can more than compensate for the eight working hours given to education. All the three essentials can thus be obtained during the years between sixteen and twenty, while the more able boys will be ready to proceed direct to a course of university standard.

(7) General studies an essential part of apprenticeship training. The engineer's need of a wider education with a better understanding of the world of to-day, its history, geography and peoples, its inter-relations, working processes, problems and interests.

(8) Education originally the privilege of the few, and these a class more concerned with ideas than with things. University and secondary education developed on lines to suit this type of mind—the minority—not so well suited to the practical-minded type—the majority—who for their education must see and handle and make direct contact with life. Hence the 'uninterested schoolboy.' Part-time education a cure for this type. All post-primary schools should be of one class—secondary—with courses modified to meet local needs. Secondary schools where possible might develop industrial and commercial sides, and boys remain at their old schools during the part-time period. The position of the works-school in the system. For their further training those not proceeding to the universities would look to the technical college—the local university.

(9) The need for the closest co-operation between the school and the workshop or office. Further widening of the interest taken by the professional institutions. Local advisory councils of the six parties concerned—the management, the worker, the school or education authority, the teacher, the parent, the boy. The evolution from these of a national advisory council.

(10) The university course, like that of the secondary schools, evolved for the scholarly type of mind. When engineering first sought help from the universities it needed men of this type of mind, the design engineer and the research worker. To-day it needs help no less in the training of the practical-minded man for production and management. Can the universities modify their long-established practice and outlook to meet this new demand and the needs of these practical-minded men ?

AFTERNOON.

Visit to the Falls of Clyde (Lanarkshire Hydro-electric Power Station).

Friday, September 7.

Presidential Address by Sir WILLIAM ELLIS, G.B.E., on *The Influence of Engineering on Civilisation.* (See p. 128.)

Mr. H. E. YARROW.—*Recent Developments in High Pressure Boilers.*

The increase in steam pressure and temperature is one of the outstanding features in the development of modern water tube boiler design, and is not confined to electric power stations only, high-pressure boilers having been introduced into many passenger and cargo vessels.

Installations are now in operation on land with pressures exceeding 1,250 lbs. per square inch, and it has been estimated that, taking as the ‘ cycle limit ’ initial conditions of 1,250 lbs. per square inch and 900° F., with two reheating and eight feed-heating stages, the consumption of about .37 lbs. of oil or .56 lbs. of coal per horse-power hour may be expected. Although such low consumption figures are not yet commercially practicable, the time may not be far distant when these high efficiencies are realised.

Boilers of very large capacity with large furnace volumes are now constructed. The tendency is to reduce the steam generating surface, increasing the rating of the boilers but recovering more heat from the waste gases by other means, such as air pre-heating, thus reducing the initial cost of the whole unit. Although the boiler surface as a whole is reduced the surface exposed to direct radiation is not reduced, and particularly is this the case where pulverised fuel is adopted, the addition of water-cooled walls adding still further to the surface exposed to radiation.

When burning pulverised fuel or oil there appears to be no limit to the temperature to which the air may be heated. With mechanical grates, unless special heat-resisting materials are used, the air temperature is, however, limited to about 400° F. if excessive repairs are to be avoided.

Rapid circulation is a necessity in high-pressure boilers, so that the steam bubbles are swept away as soon as they are formed, and every encouragement should be given to the water to circulate freely, so that tubes well inclined and as straight as possible are preferable. It is essential, however, to ensure that pure feed water only is used in high-pressure boilers, otherwise the formation of scale may occur and lead to overheating.

As boiler pressures increase it becomes more important to reduce riveted and bolted joints. Hollow-forged drums are now obtainable at a reasonable price both for the steam drum as well as the water collectors. These drums can be made with riveted ends or, for very high pressures, the drums are forged with closed-in ends, n which case rivets are entirely eliminated.

In the design of superheaters for higher temperatures the creep of materials, which has in recent years received considerable attention, has a very important bearing. From ‘ creep ’ consideration it would appear that steam temperatures of 750° to 800° F. are approaching the dangerous limit if ordinary carbon steel is used. Alloy steels will stand higher temperatures and such materials will, no doubt, be more extensively used as steam temperatures increase.

The utilisation of the coal resources of this country is of such vital importance that any development in the direction of improving the efficiency and economy of steam-generating plants will be followed with much interest. While in electric power stations coal is more or less universally adopted, in the mercantile marine the use of oil in Diesel engines is a serious competitor. It is significant to note, however, that the recent development in high-pressure boilers and steam turbines has resulted in steam machinery in combination with coal being selected by certain shipowners in preference to oil engines.

Mr. W. J. Kearton.—*An Investigation into the Throat Conditions during the Adiabatic Flow of Mercury Vapour through Nozzles, within a Unique Range of Initial Superheats.*

The paper deals chiefly with the adiabatic flow, through nozzles, of mercury vapour in thermal equilibrium. An expression is deduced giving the ratio of throat pressure to initial pressure for expansions in which initially superheated vapour becomes dry and saturated before arriving at the throat of the nozzle. The actual analysis shows that this ratio is sensibly constant. The limit of application of this expression is reached when the initial superheat is such that the vapour is just dry and saturated at the throat.

Considering expansions in which, owing to moderately high initial superheats, the vapour may still be superheated after the nozzle throat is passed, it is shown that there is a limit of application, for this type of expansion, corresponding to a certain initial superheat, where once again the vapour at the throat is just dry and saturated. Between the limits mentioned above there lies a range of initial superheats for which none of the existing analytical methods can readily be applied.

This range is investigated, and it is shown that the time-rate of mass flow per unit area of nozzle section is not a continuous function of the pressure ratio of expansion. Within the range the maximum rate of flow corresponds to the point

of discontinuity. Further it is shown that the vapour is always dry and saturated at the nozzle throat.

It is also shown that the acoustic velocity through the vapour changes suddenly at the section of the nozzle where the vapour state changes. This discontinuity confirms the statement that within the unique range of initial superheats specified, the vapour at the throat is always in the dry and saturated state.

AFTERNOON.

Visit to Shipbuilding and Engineering Works of Messrs. John Brown, Clydebank.

Monday, September 10.

Mr. A. E. L. CHORLTON.—*Oil Engines for Aircraft and Railways.*

Wing-Commander CAVE-BROWN-CAVE.—*Evaporative Cooling of Aero Engines.*

Prof. W. J. GOUDIE.—*Cycles for Internal Combustion Engines.*

Prof. E. F. D. WITCHELL.—*A Chart for the Determination of Internal Combustion Engine Efficiencies.*

The paper discusses the modification in expressions for the ideal efficiencies of internal combustion engine cycles rendered necessary by the fact that the specific heats of the working agent vary with temperature.

The ideal efficiency depends on volume ratios, heat input and the temperature at which compression begins, and a chart is described by the aid of which the ideal efficiency of a cycle with given data may be easily determined.

The expressions for the specific heats used for the construction of the chart are those for permanent gases selected by the Institution of Civil Engineers in the recent report on heat engine trials.

AFTERNOON.

Visit to works of Messrs. D. Colville & Co., Clydebridge.

Tuesday, September 11.

Prof. W. CRAMP.—*The Possible Application of High Frequency Power to Electric Traction.*

The idea of conveying electric power to a moving vehicle by *induction* (instead of by *conduction*) is attractive, since sliding contacts are thereby avoided. Ayrton, Perry and Mather appear to have made an attempt in 1896 to develop a system on this principle, but as they used ordinary power frequencies the wattless component of current became unmanageable. In 1922 M. Maurice Leblanc proposed to use a frequency of 20,000 p.p.s., and worked out (on paper) a complete system, using an ionic h.f. generator of his own design for the primary supply. In his secondary circuit on the train another ionic converter changed the single-phase current into three-phase low-frequency current, which fed the motors. This arrangement involved not only a tuned primary and secondary, but also a very special form of overhead conductor, and complicated gear for maintaining the tuning with change of load. The space occupied by the apparatus on the vehicle was very large, and M. Leblanc does not seem to have published tests of his generator, nor to have constructed his automatic tuning gear.

In 1924 the author saw that automatic tuning is really a natural feature of the Poulsen arc, and in consequence a generator of this type would immensely simplify

the problem. Further a simple a.c. to d.c. converter is already to hand in the mercury arc rectifier, if this can be used for such high frequencies. If, then, these two can be combined, transmission by induction, coupled with ordinary d.c. traction motors, becomes possible. For the past four years various research students have been at work at Birmingham on the parts of this combination, with the object of finding answers to the following main questions:

1. Can an overhead system of the type proposed act as an efficient power transformer?
2. Can the Poulsen arc be developed into an efficient generator for these purposes?
3. Will an arc rectifier operate at frequencies of 20,000 and upwards?

The progress of the work is reported in this paper, and may be summarised as follows:

1. The efficiency of transformation is very good.
2. The primary should be supplied with constant current at varying voltage, under which conditions the Poulsen arc operates very well. The overall efficiency can probably be made satisfactory by a suitable choice of voltage and current. Reliability and steadiness are not so certain, and more work is necessary in this direction.
3. The arc rectifier will function quite satisfactorily even up to 107,000 p.p.s., but some further work is necessary upon the regular maintenance of the arc.

The whole combination, consisting of Poulsen arc, transformer, mercury arc and motor, has operated in the laboratories at 75,000 p.p.s. without difficulties other than those referred to above. The thanks of the University are due to the Department of Scientific and Industrial Research for the help that has been accorded, and to the Royal Society for a contribution towards the cost of the apparatus.

Mr. B. Hague.—*Experimental Methods for determining the Distribution of Electric and Magnetic Fields.*

Dr. J. Hartmann.—*The Jet-Wave and its Applications.*

A conductive liquid jet, preferably a mercury jet, passes a constant magnetic field the lines of force of which are perpendicular to the jet. The latter touches a special electrode, which does not deform the jet appreciably. Through the said electrode and the jet-producing nozzle an electric current may be transmitted into and out of the jet. The interaction between the current and the constant field will transform the jet into a so-called jet-wave, the shape of which depends on the character of the current used in the production of the wave.

If the current is uni-directional a simple bend is produced. The latter travels forward with the velocity of the original jet, the separate particles of the wave-bend radiating from the centre of the field along straight lines. The height of the bend thus increases proportionally with the distance from the field. On this type of waves the so-called *jet-wave interruptors* for the operation of X-ray inductors are based. The jet is inserted in the primary circuit of the inductor. The current growing up in the said circuit will create a wave as described. In travelling forward the wave will hit a knife mounted between the field and the electrode, through which the current is led into the jet. The knife will cut the wave, thereby interrupting the circuit, which is not closed again till the front of a new undeflected jet has arrived at the electrode from the field. It will be understood that the wave just considered may also be employed as a member of simple relays and regulators. A characteristic of *the jet-wave relays and regulators* is their definiteness of operation.

With a simple alternating current through the jet a continuous train of regular waves is created. Approximately the waves have the shape of a sine-curve with steadily increasing amplitude. On this wave the *synchronous jet-wave commutator* is based. In the latter the wave is directed against a twin electrode consisting of two steel bars with a gap between and a knife arranged just above the gap. Above the twin electrode is arranged an electrode, the tapping-electrode, which is in unbroken contact with the wave during its motion. Obviously the wave will alternately for half a period of the current used in the production of the wave connect the tapping-electrode with the two components of the twin electrode. Consequently the device may be used for rectification of any alternating voltage synchronous with the wave-producing current. It forms the main member of *the jet-wave rectifier*, presumably

the first practical solution of the problem of mechanical rectification of high powers.

Other applications of the synchronous jet-wave are the *jet-wave frequency-meter* and the *jet-wave contact-maker*, a substitute of the Joubert-disk for the point-in-point determination of a.c. waves.

Finally the wave produced by an arbitrary current may be used in *the jet-wave oscillograph* for obtaining oscillograms of the current in question. For the motion of the point of intersection between the wave and a plane perpendicular to the original jet is conform to the current producing the wave. The new oscillograph has practically the same sensibility as a modern Duddell oscillograph.

Mr. J. G. Docherty.—*The Effect of the Velocity of Test on the Notch Brittleness of Mild Steel and Other Metals.*

The author first refers to some of the published results of notched bar bending tests, and points out the lack of agreement as to the nature of the velocity effect. The object of his experiments is to investigate this effect more fully by carrying out tests at a number of speeds, in the hope that the results obtained will throw some light on the discrepancies between the results of other experimenters. The experiments are not yet complete, but some interesting results have already been obtained.

The testing gear is designed to reproduce, as closely as possible, the characteristics of the Izod test on the standard 10 mm.$\times$10 mm. notched specimen. The energy absorbed in bending or breaking the specimen is recorded autographically. The speed of the 'striker' can be varied as desired, and in the experiments described ranged from 0·05 in./min. to 50 in./min. The standard Izod test speed is about 7,000 in./min.

The most complete series of tests was made on mild steel. The energy absorbed is shown to increase with speed of testing, the Izod figure lying somewhat above a smooth curve passing through the slow bend results.

Tests were also made on nickel steel and naval brass. In the former the energy increases slightly with speed of test up to the fastest slow bend test, but the Izod figure is about 50 per cent. lower. In naval brass, the energy absorbed increases with speed, up to the Izod value.

Observations made during the tests indicate that the propagation of the fracture is not continuous, but intermittent, as if by alternate rapid cracking and slower ductile tearing. It is suggested that the anomalous result in the case of nickel steel may be due to the existence of a critical speed, above which the cracking effect predominates, with consequent diminution of energy absorbed, and that in nickel steel this critical speed lies below the speed of the Izod test, while in mild steel and naval brass it lies above.

In addition, a series of photographs is shown, tracing the development of the fracture in a mild steel specimen.

Prof. A. P. Thurston.—*The Control of Aircraft by Supplementary Airettes or Alulas.*

Afternoon.

Visit to Greenock (Works of Messrs. John Kincaid & Co., R.N. Torpedo Factory, Watt Library and Engineering School).

Wednesday, September 12.

Report of Committee on *Electrical Terms and Definitions:* Papers by Prof. G. W. O. Howe, Prof. C. L. Fortescue, and Prof. E. W. Marchant.

Report of Committee on *Earth Pressures.*

SECTION H.—ANTHROPOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 686.)

Thursday, September 6.

Discussion on *Human Distributions in Scotland*, opened by Prof. T. H. Bryce.

Prof. T. H. Bryce.—Maps of distribution of constructions and relics of the Stone and Bronze Ages in Scotland raise the question how far such maps afford a basis for conclusions regarding the source of the cultures and the routes they followed to reach Scotland.

A glance at a map of the physical geography of North Britain shows how small is the amount of land desirable for occupation compared to the total area, and a map of the density of population at the present day indicates conditions which must have prevailed from the earliest times. Apart from areas of special density recently developed in the coal and iron districts, the general distribution of the population has been much the same throughout.

In the fully developed Bronze Age a uniform culture extended all over Scotland, and from that period onwards until early Christian and Viking times Scotland is probably to be considered a unit area. It is a question how far maps for individual types of fictilia would reveal their source.

It is obvious that such maps can only be provisional due to incompleteness of the record, and in regard to constructions of early times there is always the possibility of error due to clearing in agricultural operations.

The distribution of Megalithic tombs contrasted with short cists with beaker urns suggests that the beaker folk reached Scotland from south and east, while the chamber builders came from south and west, and the maps point to the blending of the two cultures. It is now known that a few long cairns occur on the east coast, and it may be that many have been cleared off the cultivated land; but the fact that the uncultivated upland districts of Selkirk, Peebles, Lanark and the Lothians show no Stone Age monuments invites inquiry. The hypothesis stated above holds in a general way. A map contrasting the distribution of beaker urns with food-vessel urns supports the conclusion that the latter type of vessel was later in time, and that it spread more widely.

Forts, earthen and stone, seem to be more or less uniformly distributed, but a map of the brochs brings out the local character of their distribution, except for a southern extension, which cannot but have some significance.

Prof. Alex. Low.—*On Five Long Cist Burials in Kincardineshire.*

The five long stone cists were unearthed at three separate sites along the Kincardineshire coast. The sides and roofs of the cists were formed of undressed flat stones, and in one instance the floor was paved with flat stones; the inside measurements were about 5 ft. 6 in. long and 18 in. wide. In each cist were the remains of a skeleton in the extended position. Of the five skeletons three were those of males and two were those of females.

From an examination of the skeletal remains we have evidence of a people of rather low stature—about 5 ft. 6 in. in the case of the males and 4 ft. 11½ in. in the case of one female—with somewhat broad skulls and square shallow orbits. The limb bones are well marked but not heavy. The femora show more torsion than usual and antero-posterior flattening of their shafts below the trochanters; the tibiæ show lateral flattening of the upper third of their shafts.

Mr. A. O. Curle.—*The Development of the Hut Circle in Scotland.*

Dwellings of the people in Neolithic times. Lack of definite evidence, though the occurrence of hut sites in the vicinity of the chambered cairns is suggestive. Hut sites of the Bronze Age definitely recognised by the discovery of pottery within them. The simplest form of hut circle—an oval with a surrounding bank of turf. Invariable

association of these with small burial mounds or tumuli. Characteristic relics recovered from such tumuli. Development of the hut circle, the turf wall gradually giving place to one of stone, and the oval form changing to circular. Hut circles with earth houses opening out of them belonging to the Iron Age. Mostly to be met with in Sutherland. Hut circles formed entirely of stone subdivided in the interior and not associated with cairns or tumuli evidently late, and referable to Christian times.

Afternoon.

Sir Richard Paget.—*Evidence of the Nature and Origin of Human Speech.*

(1) The acoustic nature of speech, illustrated by talking models.

(2) Phonation conveys emotional state, articulation conveys ideas. The importance of cultivating articulation. Darwin's observations on the sympathy of tongue and hand. Mouth pantomime. Lip reading by ear.

(3) Evidence drawn from various languages—Aryan, Semitic, Polynesian, &c., and American-Indian, of the gestural origin of speech. Synthetic words. Analysis of tongue and lip gestures. Tongue track diagrams. Language differences. Symbolism. Dr. J. Rae, 1862. Roots common to unrelated languages.

(4) Prof. A. R. Wallace on pantomime in modern English. His theory tested. The high survival value of words produced by pantomimic gesture of the organs of articulation.

Miss B. Blackwood.—*The Colour Top as a Means of recording Skin Colour.*

A quantitative determination of the skin colour of man can be obtained by using the Milton Bradley Colour Top. This device consists of a basal disc of cardboard, pierced by a central hole which accommodates a wooden spindle held in position by a nut. On this basal disc are placed paper discs coloured black, red, white and yellow, interlocked by means of a slit from centre to circumference, so that the proportion of each colour which contributes to the surface can be varied at will. When the top is spun the colours blend. By adjusting the proportions of the four discs till the appropriate combination is obtained, the skin colour of any individual can be matched.

The basal disc is marked off into sectors, each comprising 5 per cent. of the circumference. The number of sectors covered by each of the four coloured discs can thus be recorded, and the result expressed in percentage. This percentage cannot, of course, be considered as representing the actual amount of pigment in the skin, which can only be ascertained by some form of analysis involving its extraction, impracticable in the field.

Owing to variations in working conditions, personal acuity in colour vision, and other difficulties inherent in any technique involving colour matching, estimates obtained by different observers cannot be compared unless the personal equation is known. Experiment has shown that the range of this personal variation is approximately 4 per cent. (± 2 per cent.). This is much less than can be obtained by any other methods so far available.

It is suggested that the colour top method possesses the following advantages: It is capable of more delicate adjustment and of greater accuracy than any other device so far adopted. Matching is facilitated by the fact that the texture of the spinning surface resembles that of skin much more closely than does the glazed surface of von Luschan's porcelains. It can be used under field conditions, where the employment of any form of spectrophotometer is out of the question; furthermore, it arouses interest instead of antagonism in the individuals examined. It provides a means of recording the result in numerical form. The data thus obtained lend themselves to statistical treatment, facilitating the study of various aspects of the subject, *e.g.* age changes, the effect of racial mixture, of climatic conditions such as tropical sunshine, &c. The numerical formula also enables the skin colour of any individual examined to be reproduced at will, for inclusion in museum records.

For these reasons the colour top method of recording skin colour appears to be the best field technique that has yet been tried, and therefore to be worthy of the attention of physical anthropologists.

Friday, September 7.

Prof. T. F. McIlwraith.—*Secret Societies of the North-West Coast of America.*

The complex social life of the coastal Indians of British Columbia is due largely to interactions between the highly organised, matrilineal northern peoples and those dwelling in the patrilineal village communities of the south. Secret societies are most important in the central region, whence they have spread in either direction, affecting all phases of indigenous culture. The primary function of all branches of the organisation is the performance of dramatic dances at which supernatural beings, in reality masked actors, appear. Only members of the society can approach these visitants, so that, during the months of their intermittent sojourn, the normal social divisions are replaced by a cleavage between the initiated and the uninitiated. Transition from the latter group to the former depends upon the possession of an hereditary prerogative, which, however, remains inoperative unless sanctioned by the group. A lengthy initiation, entailing considerable expense to the candidate, is necessary to validate the step. The secret societies thus exercise religious, social and economic functions, and, in addition, the respect shown to senior members has important political significance.

Mr. Robert Kerr.—*The Gordon Munro Collection of Japanese Antiquities in the Royal Scottish Museum, Edinburgh.*

This paper described the large collection of prehistoric Japanese antiquities collected by Dr. N. Gordon Munro, of Yokohama, Japan, and presented by him to the Royal Scottish Museum. The prehistoric age of Japan falls into two principal periods, which Dr. Munro has termed 'Neolithic' and 'Yamato.' Relics of the Neolithic period have been found mostly on the sites of ancient dwellings of the early race which inhabited Japan, and especially in shell mounds. The objects recovered consist chiefly of implements of horn, bone and stone, and of vessels and fragments of coarse hand-made pottery. 'Yamato' was the name applied to itself until the seventh century A.D. by the race which invaded Japan from the Asiatic continent. Amongst the most remarkable remains of this period are the burial mounds containing stone vaults. These tombs have yielded weapons and implements of iron and bronze, and imitations of these in stone; also personal ornaments in various materials; and several types of pottery, mostly turned on the wheel.

Capt. G. E. H. Wilson.—*Deductions from the Remains of an old Agricultural System in Uhehe, Tanganyika Territory.*

In Uhehe there are the remains of an agricultural system of an ancient date. It has been noted that where these occur there are place names beginning with RU, a prefix now fallen into disuse, that these names are traceable over a large area extending from the Ruaha, latitude eight degrees south, to Rutiaha, about latitude three degrees north, when all trace is lost until the name reappears at Khartoum as Rufaa. From these deductions it would appear that at one time, possibly that of the Himyarites, there was in the neighbourhood of the Central African Lakes a great dominant race who traded with the outside world to the north via the Nile to Ptolemais and the west by way of the Ruaha to Rhapta. It also appears from these deductions that the coast line of Ptolemy can be closely identified, particularly the position of ancient Rhapta. The problem it is desired to submit for discussion and further investigation s, who were these ancient people?

Mr. G. W. B. Huntingford.—*The Hunting Tribes of Kenya.*

The hunting tribes who live in various forest regions of Kenya Colony are termed collectively Dorōbo, or, in their own language, Okiek. The majority, it appears, speak a dialect of Nandi; there are certain peculiarities which are presumed to be remnants of the original Okiek language. The most reasonable supposition is that the Dorōbo are autochthonous, and that the Nandi language has been superimposed on their own. The Dorōbo of the Kâmelilo-Kâpchepkendi district, S.E. of the Nandi Reserve, live in temporary shelters made of branches. They keep no cattle, and

have no cultivation. They possess dogs and use them in hunting, which is their only occupation. They hunt and eat practically all animals except the hyæna. They are also fond of honey. They have nothing in the way of arts and crafts. They make baskets, which form a medium of exchange with the Nandi, and with which they buy their ironwork and tobacco. They make their own bows and arrow- and spear-shafts. In dress they have adopted the Nandi style. Their social system is similar to that of the Nandi. They have seven circumcision ages, with 10-year intervals, forming a recurring cycle of 70 years. They have fewer clans than the Nandi, but the same totems. Circumcision and clitoridectomy are practised. Free love exists, but to a lesser degree than among the Nandi. They are polygamous when they can support more than one wife. The price of a wife is paid in honey-wine and fur caps. The dead are taken out for the hyænas. Such government as they have is in the hands of a council of elders. Their religious ideas are not dissimilar from those of the Nandi tribes.

Miss M. A. Murray.—*The Egyptian God of Death.*

The jackal-headed god, Anubis. The connection of Anubis with the horned viper. The dying god and the god of death.

Mr. H. Field.—*The Field Museum Syrian Desert Expeditions, 1927–28.*

Afternoon.

Sir W. M. Flinders Petrie, F.R.S.—*Southern Palestine.*

The survey of 1914 has opened up the seventy miles of ancient sites south of Gaza; among these forty cities are recorded, and half of them can be identified with the modern names. For historical purposes and dating this region is the best, as having many links with the known history of Egypt. In the past two winters the British School of Egypt has moved into this region to carry on the knowledge of Egyptian products into Palestine archæology. The first site searched was at Gerar, where an acre was cleared—about a third of the remaining city—through six rebuildings from Thothmes III to Artaxerxes. On an average the successive city levels were five feet apart, and thus quite distinct. The site was also nearly flat, and with only a slight difference of level in various parts. Thus it was an ideal place for discrimination of styles. Plans of each city recorded the level of every wall, and distinctive lettering for every chamber. Every object found—about 1500—was drawn and registered by the plans. A complete record is in this way preserved and published, while all the successive buildings are now cleared away. A scale of pottery, beads, and brick-sizes is thus formed for the study of other sites.

The historical results: Eleven granaries for the Persian army were found, holding enough to feed 35,000 men for two months; probably at least as many more have been destroyed by denudation; the latest date for these would be 457 B.C., and beneath one was an Attic vase not earlier than 460 B.C. Before the fort of Psameticus the influence was Assyrian, about 700 B.C.; and Western about 800 B.C. At 970 B.C. there was an occupation by Central Asian people, probably headed by Sheshenk of Susa: this appears to be part of the same migration which entered Asia Minor, and passed on as the Etruscan colonisation of Italy. Cremation marks both movements. Much gold was found of 1140 B.C., the age of gold abundance in Midian. Iron furnaces and great tools are of 1100 and 1175 B.C. Some iron was wrought by 1350. The use of iron chariots and furniture by 1100 is thus affirmed. The Philistines are found bringing Western pottery by 1300, long before their defeat by Rameses III. They were planted in the midst of the corn growing districts, probably to collect grain for export to Crete. The second year's work was at Beth-phelet, the home of David's guard of Pelethites. This is a key position, only accessible on one side, and commanding the only open water on the Egyptian road. The city has been examined back to 1500 B.C. but deeper parts are not yet searched. The cemeteries show that the richest age was that of Solomon; though this was the poor end of Judea, its products are better than those of Egypt or Babylon at that time. The cause of this wealth was the possession of trade routes between east and west, through Mesopotamia and the Red Sea.

Mr. H. Field.—*The Field Museum-Oxford University Excavations at Kish, 1927–28.*

Saturday, September 8.

Excursion to the Lanarkshire and Peeblesshire Cultivation Terraces described in Prof. T. H. Bryce's paper (Monday, September 10).

Monday, September 10.

Presidential Address by Sir George Macdonald on *The Archæology of Scotland.* (See p. 142.)

Dr. Arthur Raistrick and Miss S. E. Chapman.—*The Lynchet Systems of Upper Wharfedale, Yorkshire.*

In the part of the Wharfe Valley from the source of the river to the neighbourhood of Burnsall, about 18 miles, the traces of occupation from early Iron Age to Saxon and Mediæval times are very complete, but hitherto largely undescribed. A number of caves afford a full suite of late glacial and post-glacial mammalian remains, associated in Elbolton, Dowkerbottom and Calf Hole Caves, with Neolithic and Bronze Age man. In Dowkerbottom Cave an occupation throughout Iron Age and Romano-British times has been proved by Prof. Poulton and other workers, while Dr. Eliot Curwen has recently (*Antiquity*, June 1928) drawn attention to the Celtic cultivation areas near Grassington.

On the plateaux of the first limestone scarp above the river and glacial lake flats areas of Celtic lynchets have been examined in seven localities, while numerous barrows of two principal types (mound and disc barrows) occur in the same area. Roman pottery and coins have been collected from many of these sites. From the second to the eighth or ninth centuries there is a complete break, and from the ninth century onwards the Anglian settlers cultivated the lower land between the first scarp and the river flats, making settlements at most of the now existing villages. In this area the strip lynchet fields are almost perfectly complete, and have been mapped along with field names, &c., for all the area. The parish of Kilnsey with Conistone is chosen as a complete example of an Anglian village organisation which persisted through the Norman period into the fifteenth century. The completeness of the lynchets over the whole of the north-west Yorkshire dales has enabled some evaluation of the Domesday carucate for this area.

Prof. T. H. Bryce.—*Terrace Cultivation in Scotland.*

The object of this paper was to direct attention to certain groups of terraces in Southern Scotland regarding the nature of which there is difference of opinion. Examples occur at various sites in Peeblesshire, on Arthur's Seat in Midlothian, at Dunsyre in Lanarkshire, &c. They have been known for long, but archæologists have not given much attention to them. The most artificial-looking group is that at Romanno, the most striking series that at Dunsyre. The question at issue is whether they are natural formations or cultivation terraces constructed at some unknown period of the past. It is probable that all do not belong to the same category. No excavations adequate to permit of definitive conclusions have been carried out. It is suggested that a commission of archæological and geological experts should be formed to investigate these terraces thoroughly. It is probable that many examples of the same class remain unknown. An inquiry into their distribution, classification and nature would be of interest, but such an inquiry must be one conducted by a committee qualified to deal both with archæological and geological evidence.

Mr. J. Graham Callander.—*Relative Levels of Land and Sea in Scotland from an Archæological Point of View.*

Archæological evidence suggests that since Azilio-Tardenoisian times there have been two distinct general land movements in Scotland, at least in the western parts.

Relics of Azilio-Tardenoisian date in Scotland seem to be contemporary with the formation of the 25-30-ft. raised beach. Subsequent to this a considerable rise in the height of the land took place, which was followed by a sinking movement which still continues. At what period the change of movement took place is not known, but the position of monuments dating to the late Neolithic Period and the Early Iron Age or Romano-British times, will be cited in support of the claim that a considerable sinking movement in the land has taken place since those times.

Afternoon.

Dr. James Ritchie.—*Palæolithic Man in Scotland—the Evidences from the Caves at Inchnadamph, Sutherland.*

Recent excavations in limestone caves near Inchnadamph in western Sutherland have demonstrated the presence of man in successive layers covering a long period of time. The importance of the discoveries lies in their revelation for the first time of the habitation of Scotland by men of palæolithic age, during the later stages of the Glacial Period. A summary will be given of the evidences—geological, faunistic, and anthropological—which determine the ages of the various layers and of the indications of the presence of man in a deposit of upper palæolithic age.

Mr. A. Leslie Armstrong.—*A Report on Recent Excavations at Cresswell Caves, Derbyshire.*

The systematic exploration of this cave has been advanced to 43 feet from the point at which Mello abandoned it in 1874, and work is now proceeding in the large inner chamber of the cave. The total depth of the deposit is 15 feet, and consists of an upper and a lower cave-earth. Evidence of casual human occupation occurs throughout the upper cave-earth and the dominant culture has been proved to be Upper Aurignacian, with considerable Proto-Solutrean elements and some traces of intrusive Magdalenian near the top.

Upper Mousterian artifacts of quartzite and flint occur at the extreme base. A recent find of outstanding importance to English archæology is that of an engraved drawing of a masked human figure, executed upon a rib, probably of reindeer. In general character and technique the figure resembles those of Hornos and Altamira, which are of Aurignacian date. It was found in association with Proto-Solutrean implements and was encrusted with breccia.

The lower cave-earth contains two definite zones of occupation, the lowest at 12 feet. Implements of quartzite and tools of bone and mammoth ivory occur in both zones, the technique of which is Mousterian. Evidence of prolonged submergence of the lower cave-earth on at least two occasions and of climatic changes are well marked, and the occupation zones are separated by sterile layers of fallen roof slabs.

Tuesday, September 11.

Mr. Miles Burkitt.—*Prehistory in South Africa and Southern Rhodesia.*

South African prehistorians recognised the occurrence of stone implements in the Cape Province as early as the middle sixties of the last century.

The country is immense and the various amateur prehistorians isolated. I was invited last year by the University of Cape Town to undertake a long tour to try and encourage and co-ordinate the very considerable work that has been accomplished.

The industries found and the problems that have arisen are in many cases the same as those we find in Europe. Hence the importance of South Africa to the prehistorian. Similar discoveries have been made in North Africa, and this area acts as a link between South Africa and Europe.

There have been found industries belonging to lower Palæolithic cultures; typical tools as well as local variants—due probably to the material from which the tools were made—occur. Next the influence of the Middle Palæolithic culture can be detected. Two invasions of Neoanthropic man follow; these can be traced from as far north as Kenya. Besides these larger cultures at least two important local hybrids occur.

The term ‘ Bushman art ’ is really a misnomer, and in different areas the art is different. Again on stratigraphical grounds, and from considerations of styles, a sequence in the art can be determined. This is especially true in Southern Rhodesia, where three phases were recognised. The styles of the older two recall that of the Spanish Art Group II ; with rare exceptions only the last phase—and then showing a more developed style—penetrated farther south into what is now the Union of South Africa.

A study of ‘ Bushman art ’ in the Union reveals the existence of two groups ; the one to the north and west of the mountains is associated with Smithfield industries, the other to the south and east of the mountains is associated with Wilton industries.

A study of the engravings shows the existence of four phases, proved, on stratigraphical grounds, to form a sequence. During the earliest of these an incising technique was practised ; figures of the later phases are made by a pocking process.

To summarise, South Africa is a well-stocked museum, and owing to its position Southern Rhodesia is an area especially important to the prehistorian. Little geological work has so far been done, but from this point of view investigations would probably be extremely fruitful and important.

Miss D. A. E. Garrod.—*Excavation of a Palæolithic Cave in Western Judæa.*

Excavations in the Cave of Shukbah were carried out by the British School of Archæology in Jerusalem from May to June, 1928. Two archæological levels were found, the upper containing a microlithic industry of a type so far unknown in Palestine, and the lower a Mousterian which resembled in many respects that already known from the Galilee caves. A number of human skeletons were found in the upper layer, and in the lower some scattered fragments of Neanderthal man.

Prof. V. Gordon Childe.—*The Origin of some Hallstatt Types.*

At the end of the Bronze Age Central Europe was occupied by a plurality of local cultural groups, divisible by burial rites and economics into two main classes : (1) tumulus-builders practising inhumation as well as cremation, occupying chiefly the higher country and devoted largely to pastoral pursuits ; and (2) urnfield-folk, dwelling by preference in the fertile valleys, and engaged in trade and industry as well as agriculture. The so-called Hallstatt culture is nothing more than these local cultural groups when they have adopted certain new devices. The question as to its origin is therefore in the first instance the question where the distinguishing types were evolved.

The breach with the Late Bronze Age tradition is in most places best marked by the adoption of safety-pins, then of certain special types of sword, the use of iron and the deposition of harness in the graves. The fibulæ are the most instructive. Of early Hallstatt types the most primitive version of the spectacle brooch is found in Styria, where its derivation from a normal Late Bronze Age ornament is obvious, and whence its diffusion along several routes to South-West Germany, Bohemia, Moravia and Silesia, Transylvania, the Balkans, Illyria and Central Italy can be conveniently represented. The harp-fibula, no less distinctive of the early Hallstatt cultures of East Central Europe, again appears in its most primitive form in Styria. The double-twist bow fibula of contemporary deposits in Hungary, Transylvania, Macedonia, Bulgaria and Illyria might equally have spread from a similar centre.

With the spectacle brooch east of the Danube and the Bosna was associated, together with Naue’s type II, the antennæ sword which has a Late Bronze Age ancestry in the Alpine region, but the oldest specifically Early Iron Age swords appear slightly differentiated on either side of Styria at Glasinac and at Hallstatt. The creation of the above-mentioned specifically Hallstatt types might therefore be ascribed to the urn-field folk of that area. But it is noteworthy that their diffusion is in many districts associated with inhumations. And it is often in inhumation graves, laid sometimes in the midst of extensive urnfields, that the oldest horse-trappings are found. Schliz holds the Hallstatt skulls from South Germany to belong to a new race there, and it is therefore legitimate to ask whether the diffusion of ‘ Hallstatt ’ types was not due to movements of Illyrian tribes from the west of the Middle Danube plains.

Mr. W. A. Heurtley.—*Recent Excavations in Macedonia and the Dorian Invasion.*

At the village of Boubousta, in the valley of the Haliakmon in Western Macedonia, a small settlement of the late Bronze (Aegæan) and Early Iron Age was excavated by members of the British School at Athens in June 1927. The pottery obtained was all hand-made, and decorated with elaborate geometric patterns in matt paint on a red or buff ground.

The importance of the site is that it falls into line with a series of sites at which pottery of a similar kind has been found, and which, to distinguish it from the matt-painted ware of the Middle Helladic period in the south, may be called 'North Greek matt-painted.' Invariably associated with this pottery is a certain kind of raking handle, known as a 'wish-bone' handle, which has been shown by recent excavations in Macedonia to be of Macedonian origin. Consequently, wherever this handle appears it may be regarded as proof of penetration by Macedonian tribes. The stages of this penetration in the Bronze Age were as follows: Thessaly (which became a secondary centre of diffusion), Lianokladhi in the Spercheios valley, Thermon in Aetolia, and finally Boubousta and Pateli in Western Macedonia. At the beginning of the Iron Age these tribes seem to have concentrated in North Thessaly and round the Gulf of Volo, reinforced by their kinsmen from Central Macedonia.

An analysis of the pottery from Marmariani and from Volo shows that, as a result of this concentration, a fusion of these various elements with a lingering Mycenæan culture in Thessaly took place, and produced the Thessalian geometric style—one of the earliest geometric styles of Greece.

The distribution of the sites agrees closely with the recorded wanderings of the Dorians, and it is suggested that the point of departure of the eastern wing of the Dorian migration was Macedonia itself.

Mr. O. Davies.—*The Sources of Tin in Prehistoric Greece.*

Tin being unknown in or near Greek lands, archæologists have sought for the sources of Greek tin in Bohemia, Tuscany, Spain, Cornwall or Khorassan, and have supported their theories by the finds in these regions of small objects of Greek type. It is, however, doubtful if in prehistoric times caravan trade was extensively employed, and perhaps more likely that cultural intercommunication was by tribe-to-tribe barter of small objects only. Moreover, with regard to tin, some mines have recently been discovered in Greece itself near Delphi, containing a large quantity of L.H. and one sherd of E.H. pottery; though the ore itself had been completely worked out, the deposit on the inside of the crucible fragments from there turned out by chemical analysis to be tin. These mines were also worked in Hellenistic times, and other mines near opened in Byzantine days; as to other periods we have no evidence, except that if they were in use in the first century A.D. we should probably have heard of them from the geographers.

Afternoon.

Mr. S. N. Miller.—*Roman York: Excavations of* 1927.

The excavations of 1925 and 1926, as described to this Section last September, had shown that the existing walls of Roman York, in spite of their apparently homogeneous plan, represented work of different periods, and that, while the west corner of the fortress was a reconstruction of the fourth century, there was no structural work in the east corner later than the end of the second century or the early part of the third. The object of the excavations of 1927 was to bring the earlier and the later work into relation with one another.

It was discovered that the fourth-century reconstruction had extended along the north-west side of the fortress and round the north corner, but not beyond the north-east gateway. On the north-west side trenching inside the fourth-century wall, besides locating an interval-tower of that period, had revealed the existence of an earlier building, probably a barrack. The position of this disused building in relation to the fourth-century wall showed that the earlier defences on this side had lain considerably further out. Thus the accepted outline of Roman York turned out to be its outline only in the last phase of its existence. A striking feature of the

excavations was the extreme rarity of fourth-century pottery within the interior area adjoining the defences, as contrasted with its comparative abundance in the centre of the fortress. This raises the question of the size of the garrison in the late period and of the quartering of the troops, and has a bearing upon the general problem of the conditions of military service in the Later Empire.

Wednesday, September 12.

Prof. T. H. Bryce.—*A Survey of the so-called Monastic Settlement at Eileach an Naoimh.*

Rev. Canon J. A. MacCulloch, D.D.—*The Picts: Actual and Traditional.*

The Picts, their origin, their racial affinities, their customs, their language have for long been a problem, the solution of which can never be quite certain. Many things said of the Picts by classical and by early mediæval writers need not be regarded as authentic. Their later history cannot be quite clearly deciphered from existing documents.

Four main theories have been entertained regarding the Picts: (1) they were a pre-Celtic people, conquered by the incoming Goidelic Celts, adopting their language, yet also modifying it as well as their customs; (2) they were a 'Gothic' or Scandinavian people; (3) they were akin to the Scots from Ireland, and like them, spoke Gaelic, thus belonging to the Goidelic branch of the Celtic stock; (4) they were a Celtic people, whose Celtic speech was that of the so-called 'P' Celts, but with dialectic differences from Gaulish and Brythonic, yet resembling these rather than Irish or Scots Gaelic.

On the whole the fourth theory is now generally accepted, though opinions differ regarding the time of the arrival of the Picts in Britain. The actual people called 'Picts' must have given their name to other tribes, whether akin to them in race and language or not, for the name 'Pictavia' was applied to the region north of the Forth. The pressure of the Dalriadic Scots upon the Picts and the impact of the Viking conquests had important effects upon the Picts. They ceased to be called by that name, and Gaelic gradually took the place of Pictish speech.

A consideration of Pictish customs shows that these were not necessarily non-Celtic or non-Aryan. The brief notices of Pictish religion are vague, but do not suggest a cult or belief different from that of the Celtic people.

Though the name 'Picts' ceased to be applied to an actual people, who must still have had many descendants in the population of Scotland, especially north of the Forth, it survived in tradition and folk-belief. But now 'Pichts,' 'Pechts' or 'Peghs' was applied to a legendary people, more or less supernatural, of small stature and enormous strength. There is no ground for believing that the Picts were a people of short stature or that a dwarf race ever occupied Scotland. How is this tradition to be explained? Two theories are possible: (1) the name, ceasing to be applied to an actual people, lingered in folk memory and collected to itself floating legends of all kinds, especially regarding the origin of megalithic remains and large buildings; (2) such words as 'Picht,' 'Pegh,' may have been originally native names for a mythic dwarf or elfin folk, and, being akin to the name of an actual people, became eventually confused with it.

Rev. J. M. McPherson.—*Primitive Beliefs in the North-east of Scotland.*

In the north-east of Scotland belief in the Black Art has not wholly died out, but the beliefs and customs which are considered here are mainly relics of ancient nature worship.

(1) The *fire festivals* occupied an honoured place in popular celebration.

Halloween.—Till recently the Hallow Fires blazed on the hill-tops. Two distinctive celebrations appeared in the Aberdeenshire Highlands. Down to about the middle of the nineteenth century the Braemar Highlanders made the circuit of the fields with lighted torches to ward off evil spirits, and to ensure fertility in the coming year.

The Hallow Fire was designed to 'burn the witch.' As Dr. Walter Gregor tells, lads going from house to house collecting material for the fire proffered their request

in the form : 'Ge's a peat t' burn the witches.' At Balmoral the witch assumed the form of the effigy of a hideous old woman or witch called the Shandy Dann. At an earlier period the fire was believed to destroy all malignant powers.

The Midsummer fires still blaze on at least one sequestered knoll, and within living memory, in one ancient town, there was wont to be a midsummer celebration.

At Kirkwall there was a 'fiery fight' on May 24, associated with the Royal Birthday. It was really the old midsummer bonfire. The leaping through the flames was another mark of an ancient rite.

To this day, on June 24, the midsummer fire is kindled on the hill of Cairnshee, in Durris, Kincardineshire, owing to a bequest for the purpose.

But it is the *Yule* fires of which there is the most widespread evidence. Even in their present attenuated form the rites bear marks of high antiquity. There is the burning of the Clavie at Burghead.

At Lerwick there used to be a fire ceremonial on New Year's Day (O.S.). There was a procession through the town of a number of youths, dragging large blazing barrels, filled with chips and tar, and mounted on platforms of wood.

Dingwall some sixty years ago had a similar ceremonial, known as the 'burning of the crate.' On the last night of the year the crate, filled with combustibles and dragged by a horse, was set on fire to the accompaniment of much shouting and dancing. The blazing contents of the crate were scattered. This was popularly believed to be the burning of the effigy of the Norse Jarl Thorfinn. But the rite antedates the Norse Conquest, and is really the burning of the witch at the close of the year.

At Stonehaven the last night of the year still witnesses the ceremonial of the 'Fireballs.' The balls are circular in shape and about the size of a bee's skep. They are made of combustibles and well inoculated with tar. To each ball a piece of wire is attached by which it may be swung by the celebrants. Some sixty balls are now employed and swung with great gusto as the procession marches backwards and forwards along the High Street of the old town.

(2) In ancient times *pillars of stone* were objects of veneration. The megaliths that abound in Aberdeenshire were believed till recent times to be the abodes of spirits or demons. In 1649 Andro Man was brought before the Kirk Session of Elgin, charged with idolatry in setting up a stone and using some superstitious ceremonies to it, such as taking off his 'bonat' to it. Like his namesake the noted Warlock of Rathven, who 'laid off wards to the Hind Knyght,' the Elgin man is perpetuating an ancient worship. The practice does not seem to have died out, for according to Bishop Chisholm a farmer in Glenlivet 200 years later went round the marches of the farm of Auchorachan reciting certain words and placing upright stones.

(3) In the uplands of the north-eastern counties there are many evidences of the survival till quite recently of primitive *agricultural* rites.

There was the ceremonial associated with the 'streeking of the plough' in the autumn. When the plough was first put into the soil after harvest, a semi-religious rite was observed. There was a meal partaken of in the field of a sacrificial nature. There was an offering to Ceres laid upon the plough and to be touched by none or else put under the first furrow. This custom—the *proarosia* of Greece—continued till well through the nineteenth century. It was found in Buchan, Cairney, Strathdon, Glenlivet, Strachan.

The 'clyack sheaf,' or 'maiden,' has been cut and gathered by many still living. The best part of the field was left to be cut last for 'the maiden.'

(4) Beliefs associated with *birth* and *death*.

(*a*) *Birth.*—Fecundation was believed by some to be due to partaking food on which a male cat had deposited semen. In 1654 Jean Sympson, a parishioner of Rothiemay, asserted she had 'cats in her bellie.' Her mother shared this belief.

The belief is not wholly extinct yet, for in some parts of the Highlands of Banffshire there are people who have a great dread of a male cat jumping upon the table.

Other rites to promote conception were performed by married women who had remained childless.

At Melshach Well, near Wardhouse, Aberdeenshire, a fertility rite is described by an observer. A large number of women—childless matrons—were seen with their garments fastened under their arms, hands joined, dancing in a circle. An old woman in the centre kept sprinkling them with water from the well. A well of similar virtue was the Bride's Well at Corgaff.

Contact with a stone of virtue might induce pregnancy in barren women. Such a

stone was the 'knocking stone' in Braham Wood, near Dingwall. Clach-na-Bhan in Glenavon was said to ensure easy delivery to the wife who was chaired in it, and a husband to single women.

The Couvade. There are instances of the pseudo-maternal couvade. A man or woman simulates the pangs of labour and thereby relieves the mother from whom the pains are believed to be transferred to the actor. Two cases occur in Lumphanan, Aberdeenshire. Elizabeth Sang, wife of John Jameson in Auchinhove, being lying in bed undelivered, Margaret Clerk in Lumphanan cast 'her haill panes, dolouris and tormentes' upon John Jameson, her spouse, from which he never recovered. There was a fatal ending to this transfer.

In the second case the pains are transferred not to the husband but to another man—probably a dependant—who was 'exceedinglie merverlouslie trublet,' but as soon as the gentlewoman was delivered the pains departed from him. This was in 1595. In 1650 a case of transfer occurs in Insch where the pains are laid upon a woman, who manifests all the symptoms of being in travail.

(*b*) *Death.*—There is some evidence that in the north-east there was once practised the custom of accelerating the end of the aged and diseased. At Alves in Morayshire in 1663 a case is reported to the Session of some people in Easter Alves 'ringing the millen bridle' upon an aged woman to hasten her death. From the details it almost seems to have been customary. The method was probably by strangulation.

Rev. A. C. MacLean.—*Celtic Folk-tale in the Light of Archæological Research.*

Folk-tales, like folk-songs, when the medium of the written word was not in common use among the people, held a place of very especial honour. Like the folk-song, the folk-tale must neither be 'corrected' nor 'improved,' and the narrators of traditional folk-tales, possessing as they did the gift of *verbatim repetition*, were held in very high honour as 'masters' in this especial sphere. The accepted folk-tales of the people were guarded by rigid literary laws. Accordingly folk-tales, genuine and properly used, become an invaluable 'control' to verify the results of archæological research.

In the class of folk-tale which has become confused the narrator had lost the art, or he had endeavoured to 'improve' his tale; for research purposes this type of confused tale is almost useless.

The other class is what may, very properly, be called the direct folk-tale, ancient, genuine and unspoiled in oral transmission from narrator to narrator in successive generations. This type of folk-tale is invaluable and very rare.

In August 1908, in the Lews, the present writer was able to induce an old man, seventy-five years of age, to tell a folk-tale, an unconsidered trifle from his point of view, of Callernish. The old man got the tale about 1840, while the narrator, who gave him the tale, got it about 1770–80; and the folk-tale was known to be old then. Thus, long before the late Sir James Matheson of the Lews carried out his excavations at Callernish, in 1858, folk-tales were associated with Callernish.

Further, the evidence of the 'overground' phenomena, together with the evidence of the 'underground' phenomena at Callernish, is in complete accord with the folk-tale told—after the traditional manner—by the peat fires on winter evenings in the Lews. The genuine and traditional folk-tale of the common people in the west corresponds exactly with the accepted results of archæological research as established to-day.

Exhibit.

Photographs of Dentition of three Bronze Age Skeletons found in Glasgow in 1928, shown by Mr. J. Menzies Campbell.

SECTION I.—PHYSIOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 686.)

Thursday, September 6.

Dr. H. E. C. Wilson.—*Nitrogen Retention.*

The nature of the material stored during nitrogen retention is reviewed in the light of: (1) Voit's idea, which maintained that the food protein was built up into a labile

circulating protein, which was metabolised by the cells relatively easily as compared to the more stable tissue protein ; (2) Pfluger's theory, on the other hand, held that all ingested protein became an integral part of the living cell before it was metabolised. The experiments planned on the superimposition method, and both the nitrogen and the sulphur in the intake and output being estimated, show that when equilibrium is attained the body excretes qualitatively the same material as is ingested. During, however, the three days when the nitrogen output is rising to the new level, the material retained is found to be relatively sulphur poor. Correspondingly when the nitrogen output falls the material lost is relatively sulphur poor. The evidence seems to show that at any time the material in transit is poor in sulphur and does not correspond qualitatively to muscle tissue, as is the case when there is a definite building up of tissue. This is in agreement with the evidence that the sulphur moiety of the protein molecule is more quickly metabolised than that of the nitrogen.

Dr. W. A. Burnett.—*Chronaxie.*

Discussion on *Cell Structures.* (Prof. J. Bronte Gatenby ; Dr. Rogers Brambell.)

Dr. Rogers Brambell.—The terms 'Golgi Apparatus' and 'Golgi Bodies' should be confined to those cell structures which can be shown to be homologous to the internal reticular apparatus of the neurone. Such structures are found in all animal cells properly examined. The relation of the Golgi apparatus to vacuoles and other cell structures is discussed, with special reference to the 'vacuome' theory of Parat. The function of the Golgi apparatus in cell metabolism is obscure, but it appears to be a centre of formation of yolk and secretion, and probably is concerned with the formation of the Nissel substance in the neurone, as well as with the formation of the acrosome in spermatogenesis. Artefacts produced in colloidal emulsions supply evidence concerning the chemical composition and physical state of the Golgi apparatus in the living cell.

Friday, September 7.

Joint Discussion with Section M on *Lactation and Nutritional Factors allied thereto.* (Dr. H. E. Magee ; Prof. E. P. Cathcart, C.B.E., F.R.S. ; Capt. J. Golding ; Dr. N. C. Wright.)

Dr. H. E. Magee.—It has been abundantly shown that at the height of lactation, heavy milking animals habitually lose more calcium and sometimes more phosphorus from their bodies than they can assimilate. This loss of calcium, if continued through repeated lactations without adequate recuperative periods, eventually ends in failure of breeding capacity, a result which is accelerated by diets poor in calcium. Attempts to make good the loss of calcium by feeding large amounts of it in soluble or insoluble form have proved only partially effective. Recent work has shown that ultra-violet light and cod-liver oil lead to a greatly increased retention of calcium and sometimes of phosphorus at all stages of lactation by diminishing the fæcal excretion of these elements.

Prof. E. P. Cathcart, C.B.E., F.R.S.—I think the marvellous phenomena involved in mammary gland activity are lost sight of in the emphasis laid on the economic aspect of milk production. Far be it from me to stress the apparently academic versus the economic aspect of the problem. I am alive to the importance of the economic side, but if advance is to take place the purely research side must not be neglected.

After all, what do we really know about the secretion of milk, about the formation of its characteristic constituents, of this gland which keeps its secretion so approximately constant in percentage composition ? It may be true that selective breeding has increased the total yield, but it has done but little to influence the composition. As regards the exact mode of formation of the protein carbohydrate and fat, I think it can be said definitely we know nothing. To me it is a true matter for wonder. A gland which only functions under, it is true, a physiological but very specific stimulus —what can be said definitely and unequivocally of the actual nature and source of origin of the stimulating substance ?

A gland further which gives rise to products like casein and lactose, which, so far as the normal organism is concerned, are literally foreign products—how does the peculiar protein which stands in a class by itself as phosphoprotein arise ? What is the mother product ? Is it synthetised, as Meigs and others have suggested, from the amino acids which circulate in the blood ? Ultimately it must be derived from amino acids, but what is the nature of the synthesis, and why does the mammary gland incorporate into its synthetic protein product phosphorus ?—so far as I know a unique synthesis. Is it possible that the real source of the casein is indirect from an amino acid foundation ? Is it formed, as Basch believed, from the nucleoprotein ? Even the other proteins present in milk, although they are not so completely divergent as casein, are not identical with the proteins of the plasma and lymph which bathe the gland cells.

The same difficulties are also true so far as lactose is concerned. Here you have again formed a foreign sugar and a sugar, moreover, which has, so to speak, a low biological value—a sugar which is not readily attached, which is not readily absorbed, and which, when it does enter the blood stream, is excreted ; a desaccharide built up out of dextron and galactose. Obviously the dextrose of the blood may be regarded as the parent substance, but whence and how does the galactose arise ? It is true that a certain amount of galactose is found in the lepoid material of brain substance. We have no doubt direct evidence in prolonged lactation of a drain of material from tissues of the animal organism like bone, &c., but so far as I know there is no evidence of wasting of the brain. It must be formed locally. How and under what conditions does this change in molecular structure take place ? And the fat : from whence is it derived ? Is it from changes in the gland cells, from fat transported in the blood stream or, as Meigs and his co-workers suggest, is a synthesis from a phosphatide basis accountable ?

There is, I think, very clear evidence that milk is a product of the secretory activity of the cells of the mammary gland, but when one reads the literature on the subject one is impressed with the depth of our ignorance as to what actually takes place. It is a field more or less ignored by the physiologist, the true Cinderella of the secretions.

If we admit that the physiologist's ignorance is profound as regards the synthetic activity of the gland, what about empirical evidence on the alteration of the composition of the milk as the result of feeding ? One would have expected that here the field of the practical expert who has little or no use for fancy academic discussions on fundamentals the evidence would be striking and plain. Not a bit of it. There are just as many contradictory facts as in the other. Why, the practical man cannot even, on a fixed diet, make that poor long-suffering animal the cow produce milk of constant amount or constant quality day in, day out. Do what he will, he gets variations and fluctuations of unknown origin. Further, the practical men are not agreed as to the power of change of diet to influence the composition. You find one set of workers working under what one might assume to be sound practical conditions asserting that a diet rich in carbohydrate and poor in fat causes the production of a milk poor in fat, a condition which can be put right by increasing the fat content of the food. And you find others like Jordan, who assert flatly that the fat content of the diet is without effect on the fat content of the secreted milk ; that it is the breed of cow which alone counts. And the same is true as regards the protein and lactose content ; the voices of the investigators refuse to chant in unison.

The fact is that the fundamental factor is that we are dealing with a real secretion, a secretion which is peculiar to the particular species, perhaps also in a minor degree to the particular animal. It may be possible to bring about a variation in quantitative output to increase the absolute amounts of particular substances secreted in the course of the twenty-four hours, but not to alter appreciably the percentage composition. But before anything like a real opinion on milk formation and the factors which may influence it can be arrived at, it is essential that more light be thrown upon the actual process of milk secretion. It is primarily a physiological investigation, and the agriculturist who wants real knowledge and not mere empiricism in his work has a right to demand that an attempt at the solution of this problem be made.

Incidentally this ignorance justifies, if any justification be even thought necessary, the foundation of a Dairy Research Institute in the west of Scotland. Research work which will contribute towards true economy in production, and will do something towards the cessation of the murder of dairy herds, will repay itself a thousandfold.

Capt. J. Golding.—A physiological liquid such as that produced by the lactating mammal reveals an interdependence of component parts. In the study of these

relationships the united efforts of the agricultural chemist and physiologist are necessary. Milk itself must be considered not only as a ready formed liquid, but as a link between succeeding generations, in any stage of the formation of which the true significance of these interrelationships may be sought.

The extremely complicated component known as milk fat is, as it were, cut off from its fellows by its physical condition in milk; the relationships of its components to other constituents must, therefore, be sought in earlier stages of the formation of milk fat. Among these components, vitamin D, the antirachitic and calcifying vitamin, is intimately connected, not only with the deposition of calcium in the bones of the fœtus, but later through the milk in the bones of the young mammal.

In a series of experiments conducted at the National Institute for Research in Dairying, Reading, and extending over seven years and involving prolonged feeding of over sixty cows in all, the milk was weighed and tested for fat at each milking and the effect of various winter rations compared with and without the addition of cod-liver oil as a concentrated source of fat soluble vitamins. In the earlier years of these experiments, when the difference between vitamins A and D had not been recognised, growth of rats fed on butter prepared from the milk of the experimental cows was taken as a criterion of richness in fat soluble vitamin. In these earlier experiments a tenfold difference was observed in the growth-promoting properties of the butter produced from cows fed on a diet of concentrates, seeds, hay and mangels, as compared with the butter from cows fed on a ration containing cod-liver oil or green grass. That is to say, that 0·1 gram of either of the latter was equivalent in this respect to one gram of the former.

Our subsequent experiments have confirmed these results and indicate that the vitamin A and the vitamin D are derived from the food and that a good winter ration for cows, containing silage and hay, may produce an antirachitic butter of moderate potency. Doses of cod-liver oil above two ounces may improve the antirachitic value of this butter. If, however, the control ration is composed of straw, mangels and concentrates, the difference between the controls and the cod-liver oil fed cows is much more marked in this respect. The vitamin A is also increased by feeding kale in winter time, but without increasing the vitamin D.

Experiments have also been carried out on the effect of this cod-liver oil feeding on the other constituents of the milk and an increase in the percentage of total calcium by feeding cod-liver oil has been demonstrated by Dr. Mattick in my laboratory.

Turning to a review of the percentage composition of the milk as a whole, charts illustrate the variation in the fat content and weight of milk of control cows in some of the groups under experiment. The variations found in a study of the milk during the lactation period revealed the fact that the nature of each cow in respect of milk yield and fat is characteristic of the individual. It also appears that within the limits of adequate nutrition diet has, as a rule, no direct permanent influence on the percentage of fat in the milk. Even when the volume of the milk yield is increased by previous management and feeding the percentage of fat seems to be unaltered beyond the limits of variation due to other causes.

It came as a surprise to find that when cod-liver oil was included in the diet of a cow in excess of a certain amount the percentage of fat fell to a degree below the limits of daily variation.

Diagrams exhibit the effect in the 1925 experiments which occurred with four ounces, and in the 1926 the depression was observed only when six ounces were given. Last winter the depression was very slight and observed only when eight ounces were given, and this spring a further series of experiments with oils from various sources showed a varying depression of fat in some cases only.

In other experiments the unsaponifiable fraction from the cod-liver oil was fed to four cows but produced no depression.

A study of the results indicate that it is not the oil itself which produces this unusual and unexpected effect on the richness of cows' milk but a constituent which varies in amount in different oils. The alterations which have taken place in the preparation of cattle cod-liver oils during the seven years over which the experiments have extended, may be responsible for the variations observed.

This unexpected effect sometimes produced by cod-liver oil has been taken into account in estimating the increase in vitamins produced in milk by feeding cod-liver oil as a source of vitamins A and D.

Whether or not the constituent of cod-liver oil which is responsible for the

depression of the percentage of fat will be of use in the study of lactation, it seems certain that the richness of the diet in vitamin D is a factor which cannot be neglected.

Dr. N. C. Wright.—One of the preceding contributions has dealt in general terms with the calcium metabolism of lactating cows. In this paper the actual reactions controlling calcium secretion in milk are discussed.

The concentration of calcium in milk is more than ten times higher than that in blood ; that is to say, the milk cells appear to have the property of selectively absorbing this element from its very low concentration in blood plasma. Physico-chemical investigations on artificial systems have provided evidence that two general reactions exist which may cause this accumulation of calcium in milk : first, the action of the casein, which is synthesised in the milk cells of the mammary gland from the freely diffusible amino-acids of the blood (Cary) and is capable of causing a selective absorption of calcium by the formation of the slightly dissociated calcium caseinate ; and second, the process of supersaturation of this caseinate solution with calcium phosphate, leading to the formation of a colloidal and non-diffusible solution of this salt, which is consequently trapped in the milk cells. Such supersaturation may be expected as a result of (*a*) the free diffusion of calcium ions from the blood, and (*b*) the presence of high concentrations of phosphate ions due to the breakdown of the phosphatide molecule in the formation of milk-fat (Meigs).

Evidence that these two general reactions control calcium secretion is provided from the three following facts : (1) previous work has already shown that the greater part of the calcium in milk exists either as caseinate or as colloidal phosphate ; (2) the calcium content of milk is very constant, a fact which we should expect if calcium secretion is governed by a physico-chemical equilibrium in which the diffusible blood calcium is itself constant ; and (3) the concentration of calcium in milk should be influenced by just those factors which influence calcium deposition in bone (an analogous process of supersaturation). Experiments with Vitamin D and ultra-violet radiation support this fact.

Mr. J. S. Fulton and Prof. B. A. McSwiney.—*Pulse Velocity in Central and Peripheral Arteries in Man.*

Measurements of pulse velocity have been made in the different arteries of man by use of the hot wire sphygmograph. In the arm the pulse velocity of the brachial artery is found to be lower than the pulse velocity of the radial artery, which indicates that the extensibility of the brachial is greater than that of the radial artery.

Mr. W. D. Paterson.—*A New Type of Recording Oscillometer.*

In the course of an investigation into the rapid increase of blood pressure in man during the onset of muscular exertion, it was considered desirable to obtain values for diastolic in addition to systolic pressure in the brachial artery as frequently and accurately as possible. Under such conditions the auscultatory method was found to be almost impracticable, and none of the well-known instruments indicating or recording air pressure oscillations in the pneumatic armlet proved adequate.

Eventually a new type of recording oscillometer was designed, and this proved capable of giving a large uninterrupted record of the series of oscillations due to arterial pulsations even during quite a rapid continuous fall in the average armlet pressure. As the base line traced out is regular and horizontal, the rapid diminution in size of oscillations immediately following a plateau of maximum range provides an easily recognisable index of diastolic blood pressure, in close accordance with the marked decrease in loudness of the sounds heard during auscultation.

The instrument is so sensitive that respiratory variations in blood pressure are clearly shown, but a mercury manometer, though in free communication with the pressure chamber of the oscillometer, is immune from any fluctuations and so records the average armlet pressure well.

By employing a double overlapping armlet, a very sharp criterion of systolic pressure can easily be obtained. This index, also sensitive to respiratory fluctuation of pressure, consists in the initial definite appearance of oscillations after their complete absence during higher armlet pressures.

In this way systolic and diastolic pressure indices and pulse rate can all be included in a single ink trace and obtained every half-minute or so, even from a subject undertaking moderately heavy work on a stationary ergometer.

Dr. F. W. Edridge-Green, C.B.E.—*Simultaneous Colour Contrast.*

1. The colours seen by simultaneous contrast are due to the exaggerated perception of a real, objective, relative difference which exists in the light reflected from the two adjacent surfaces.

2. A certain difference of wave-length is necessary before simultaneous contrast produces any effect. This varies with different colours.

3. A change of intensity of the light of one colour may make evident a difference which is not perceptible when both colours are of the same luminosity.

4. Simultaneous contrast may cause the appearance of a colour which is not perceptible without comparison.

5. Both colours may be affected by simultaneous contrast, each colour appearing as if moved further from the other in the spectral range.

6. Only one colour may be affected by simultaneous contrast, as when a colour of low saturation is compared with white.

7. When a false estimation of the saturation or hue of a colour has been made the contrast colour is considered in relation to this false estimation. That is to say, the missing (or added) colour is deducted from (or added to) both.

8. A complementary contrast colour does not appear in the absence of objective light of that colour.

9. The negative after-images of contrasted colours are complementary to the colours seen.

Afternoon.

Joint Meeting with Sections D (*q.v.*) and K for communications on Experimental Biology.

Monday, September 10.

Dr. R. H. Thouless.—*Resistance and Polarisation in the Human Skin.*

When the electrical resistance between two non-polarisable electrodes placed on different parts of the skin is measured by a rapidly alternating current (of several thousand cycles per sec.), the resistance is found to be very much less than when it is measured by a direct current. Einthoven regards this as due to the fact that the major part of the resistance to a direct current is due to the high resistance of a thin layer of the skin which behaves as the dielectric to a condenser system of sufficiently high capacity to offer only slight resistance to a rapidly alternating current. Thus the main part of the resistance measured by such a current is not that of the skin but of the underlying tissues. Gildemeister, on the other hand, attributes the main part of the apparent resistance to a direct current, not to the skin resistance (which on this theory is small), but to a back E.M.F. of polarisation, the effect of which is very largely eliminated by the use of rapidly alternating currents. These may be called the 'capacity' and the 'polarisation' theories respectively. Failure to obtain the psycho-galvanic reflex (P.G.R.) with such alternating currents is explained on the capacity theory by the supposition that the reflex is a change in skin resistance alone and not in that of the underlying tissues; on the polarisation theory by the supposition that the reflex is not a change in resistance but in polarisation.

Gildemeister's principal evidence for the polarisation theory was obtained from an experiment in which the body was balanced on a Wheatstone bridge with a variable inductance (L) in the fourth arm adjusted to bring the bridge to a sharp balance by compensating for the phase change in the alternating wave due to the capacity (or polarisation) of the system. He showed that if ΔW were the difference between the resistance as measured on the bridge and the value to which it approximated as the frequency was increased indefinitely, then, on the capacity theory, $\Delta W/L$ should be constant for all values of the frequency (f). He found that this was not the case but that $\Delta W/fL$ was more nearly constant (as would be expected on the polarisation theory).

Repetition of this experiment confirms Gildemeister's result. Experiments reported to this section last year which pointed to the capacity theory must, therefore, be regarded as valueless. Einthoven's own experiments are also inconclusive.

On the polarisation theory, we should expect an increase of direct current to be accompanied by a decrease of apparent resistance, since as saturation of polarisation

is approached, the ratio of the E.M.F. of polarisation to the external E.M.F. will be reduced. For the same reason, increase of alternating current should reduce the value of the compensating inductance (L) required for a bridge balance. Both of these expectations were confirmed by experiment, a result which is inexplicable on the capacity theory. A crucial experiment was attempted by finding whether the passage of a direct current large enough to produce saturation of polarisation would reduce L to zero. This experiment proved impracticable.

The P.G.R. was found to be present when measured by alternating current, but reduced in magnitude and inappreciable with higher frequencies than about 2,500 p.s. It must be regarded, therefore, not merely as a change in the total amount of polarisation in the skin but as a reduction in the polarisability of the skin.

Dr. I. Leitch.—*On the Metabolism of Iodine.*

Presidential Address by Prof. C. Lovatt Evans, F.R.S., on *The Relation of Physiology to other Sciences.* (See p. 150.)

Prof. J. J. R. Macleod, F.R.S.—*Fatty Acid as a Source of Carbohydrate in Diabetes.*

Tuesday, September 11.

Dr. H. E. Magee.—*Some Factors that influence the Movements of the Surviving Mammalian Intestine.*

The occurrence of organic lesions in the alimentary canal of cavies fed on deficient diets suggested that these might have a remote effect on the intestinal movements as recorded in vitro. Groups of cavies were fed on diets deficient in fat soluble vitamins and in Ca, Na and Cl, and the movements of surviving ileum from them recorded and compared with tracings from the ileum of control animals. In the case of the former, varying degrees of disordered rhythm of a hypersensitive or of a hyposensitive type were obtained. The responses to adrenalin, bicarbonate and phosphate were also abnormal in type. Other experiments on the surviving intestine of cavies and rabbits have shown that the musculature is relatively insensitive to electrolytes of physiological importance with few exceptions when acting from inside the lumen.

Prof. F. G. Baily.—*The Measurement of Ultra-violet Radiation.*

A method is described of measuring the ultra-violet radiation from any lamp in definite units, or the dosage of a treatment. Photographic printing paper responds to those radiations which are medically active. What is required is a reliable standard and a scale based on the standard, by which measurements by different people may be in definite units. An arc lamp is described which is constant and reliable, with steady flame and uniform radiation over long runs and on successive runs. It is not intended for medical use, but is a standard unit of ultra-violet radiation, and is also suitable for work needing a steady source, the regulation requiring no skill and the electrodes being cheap.

For comparison of lamps a suitable medium is blue ferro-prussiate paper of a particular make, which is uniform in quality, permanent in colour, and only requires washing for fifteen minutes. Silver papers are not so uniform, but they are sometimes convenient. A set of papers is exposed for a series of times, ranging from 30 seconds to 13 minutes, to the standard lamp at three feet distance, yielding 27 shades easily distinguishable. In the pale and dark shades the steps differ by 20 per cent., but between one and six minutes a difference of 10 per cent. is distinct. With this series, the effect of a standard exposure of similar paper to any lamp can be determined on the scale and defined in terms of the standard.

To ascertain the quality of the radiation, absorption glasses are used, Crookes glass passing radiations to a wave length of 350 $\mu\mu$, lead glass to 320, Vita glass to 280, and quartz to 200. The resulting tints are determined on the scale, and the lamp is defined by the four numbers, showing the character of the radiation as well as the strength.

The dosage given to a patient from any lamp is measured by exposing a paper along with the patient for the time of the treatment, the resulting tint giving the number of standard lamp minutes. To avoid very dark tints, the distance of the paper may be increased, as the effect on the paper is proportional to time divided by square of distance. Variations of the lamp do not matter, for paper and patient receive the same treatment.

It is proposed that small books of the standard series of tints, sheets of suitable photo-paper and standard absorption glasses shall be obtainable, to enable any practitioner to have definite knowledge of lamps and dosage.

Demonstrations :—

(*a*) Dr. W. A. Burnett.—*Chronaxie.*

(*b*) Dr. F. W. Edridge-Green, C.B.E.—*Colour Contrast.*

(*c*) Mr. W. D. Paterson.—*The Recording of Blood-pressure in Man.*

(*d*) Mr. F. Gairns.—*The Staining of Nerve-endings by a modified gold-chloride technique.*

(*e*) Dr. Wishart.—*Metabolic Research Apparatus.*

(*f*) Mr. McCall.—*A Device for recording at a distance the variations of blood-pressure.*

(*g*) Dr. R. C. Garry.—*A Demonstration of Trendelenburg's Technique for showing bowel peristalsis in vitro.*

(*h*) Mr. M'Farlane.—*Micro-determination of Phosphorus.*

SECTION J.—PSYCHOLOGY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 687.)

Thursday, September 6.

Dr. C. S. Myers, C.B.E., F.R.S.—*Educability.*

The problem of educability is here considered from the standpoint of vocational psychology—the capacity to profit from training with a view to proficiency in some occupation.

The experimental evidence on the relation between innate ability and trainability is at present highly conflicting. In some tasks individual differences in innate ability seem the more important, practice producing little change in these relative differences ; in others a very poor correlation has been claimed between the ranking of persons based on their initial performance of a task and their ranking based on performances after equal practice at it. The causes of this conflict are examined. A psychologically effective measurement of improvement and improvability is shown to be extremely difficult.

Despite his neglect of educability, the vocational psychologist's success may be due to the number of different abilities which he examines for any one occupation, to the differences in educability in these different abilities, and to the use which he makes of intelligence tests in his guidance and selection.

A fundamental distinction must be drawn between (*a*) the mechanical, repetitive 'practice' of an innate ability which results in a precocious ripening, or even in a hypertrophy of it ; and (*b*) that higher 'training' which leads to the acquisition of the best attitude, the best technique and style and an adequate knowledge of general guiding principles, enabling the best use to be made of an innate ability. Laboratory experiments, *e.g.* on the transfer of practice, have been hitherto necessarily concerned chiefly with the former ; whereas in true educability and in every-day life, the latter plays a most important part.

Just as we distinguish general, group and special abilities, so we may distinguish general, group and special educabilities. Occupations involving high-level abilities rightly demand a wide education, followed by an increasingly specialised training; whereas the training for occupations involving low-level abilities should be initially specific, proceeding, so far as is possible (considering here the limitations of intelligence), in the reverse direction. Experimental evidence indicates that low-level motor abilities show no correlation with one another, whereas the more highly co-ordinated motor abilities fall into groups, the members of which are inter-related. This and their changing correlation with practice have an obvious bearing on the problems of training and trainability.

Mr. R. J. Mackay.—*Some Human Aspects of Industrial Rationalisation.*

The term 'Industrial Rationalisation' connotes the efficient localisation and route-ing of human power. Some results of experiments with vocational tests in an industrial concern. Need for well-informed vocational guidance bureaux. The further extension of 'Rationalisation' should provide channels for the more suitable placing of all grades of personnel. We may expect a growing industrial and commercial absorption of types normally regarded as 'professional,' including a stronger demand and more equitable reward for the scientific worker.

Dr. M. Collins.—*Variations in Colour Vision as shown in Colour Equations.*

Mr. H. E. O. James.—*The Present Position in regard to Theories of Colour Vision.*

Afternoon.

Mr. F. M. Earle.—*The Principles of Vocational Guidance.*

Dr. A. Macrae.—*Practical Methods of Vocational Guidance.*

Mr. F. M. Earle and Dr. Macrae.—*Demonstration of Tests of Vocational Guidance.*

Friday, September 7.

Dr. W. Brown.—*Personality and Methods of Mental Analysis.*

The structural and dynamic characteristics of personality have been studied and elucidated in recent years by special methods of mental analysis—on the one hand by quantitative methods (statistical correlations), and on the other by the qualitative methods of hypnotism, psycho-analysis and other forms of what may be called 'deep analysis.' In each case the inferences drawn from the method need to be carefully distinguished from the method itself, and in several the influence of the experimenter upon the subject needs close scrutiny and careful assessment. A definition of personality and an indication of its general structure in the light of modern knowledge.

Presidential Address by Prof. T. H. Pear on *The Nature of Skill.* (See p. 168.)

Afternoon.

Dr. J. Drever.—*Errors in Spelling.*

Mr. A. R. Knight.—*The Psychological Make-up of the Business Executive.*

Mr. A. Hudson Davies.—*A Method of comparing Abilities in Colour-matching.*

The method described was devised for purposes of research on selection tests for printing operatives. Ordinary tests for colour-defect are not suitable for selection purposes, since the nature of a colour-printer's work soon discovers crude

deficiencies. The errors which cause financial loss to printing firms are usually minute misjudgments of hue and saturation. The more elaborate spectrometer investigations of individuals demand a skilled technique, are fatiguing to the subject, are difficult to interpret in terms of norms, and take too long to be an economic proposition as selection tests for industrial purposes.

Further, existing methods are not flexible. A printer works under varying conditions of illumination, and in lights of continuous varying spectral composition. His colour judgments may be made under every disadvantage of adaptation, simultaneous or successive contrast affecting the surfaces he is comparing, or fatigue. The problem was to devise a simple portable test, interesting and involving a situation similar to the ordinary colour matching operation, and with such a test to investigate individual differences in the ability to discriminate small differences of saturation and of hue, and in the ability to match colours. Further, to find the effect on these functions of—

1. Variations of the absolute and relative illumination of test surface and background.
2. Background colour (contrasting or similar).
3. Education in colour matching.

Other allied problems are absolute memory for colour, and the connection between ability to discriminate a difference of colour and ability to specify what the difference is. A printer must know how to correct the colour of his print.

Various methods were considered and rejected, either on the ground that they did not lend themselves to the investigation of these problems or else that the necessity for a psychophysical method involving tedium and loss of interest to the subject would tend to vitiate results.

The final test took the form of sets of small coloured discs, prepared by a technique which ensured that a step-by-step transition in saturation occurred through the set, even though individual steps were too small for certain discrimination. Three sets are being tried, blue, yellow, red, and each set consists of two duplicate series of sixteen samples.

In the test the subject first sees a single series scattered at random on a table in a dark room, under a standard and uniformly illuminated field of approximately daylight quality. The series is set on a neutral background, but any coloured background can be used. The first test is to arrange the series in order of saturation.

In a second test the subject is given the duplicate series and is asked to match each member with its duplicate in the first series, which is again arranged at random. The samples are numbered one to sixteen, and the results are scored by taking the sum of all departures from true order in the first test and from true matching in the second. A high score indicates low discriminative ability.

The validity of the series is assured by analysing the placings of the discs. If in a table of placings or of matches by the accumulated subjects the mode of the frequency distribution of the placings of each disc is in its proper place (*i.e.* if sample 4 is placed most often in place 4, or matched most often with No. 4 of series 2) then correctness of gradation can be assumed.

Though the tests have not yet been carried out on enough subjects to generalise results are encouraging. Out of the first ten tested, two individuals have been found to be far superior to the rest in every variation of the tests. Tests are still proceeding and hue-gradation series are being constructed.

Miss E. M. Yates.—*Experimental Work upon Transfer of Training.*

1. *Problem of Transfer.*

The doctrine of general training or formal discipline states that the effect of training in any specific form of mental activity may be transferred to any other activity of the same form, although dealing with different material. It may be expressed more simply: 'How far does the training of any mental function improve other mental functions?'

2. *General form of experiments on Transfer.*

The essential order of experiments may be summarised thus: (*a*) test, (*b*) training in similar but not identical material, then (*c*) further test. There are two groups of subjects, the first, known as the trained group, is given 'a,' 'b' and 'c,' the second is given 'a' and 'c,' but not 'b,' (the training between the two tests).

By comparing the relative scores of the two groups in ' a ' to ' c ' the effect of the training ' b ' can be estimated.

It is essential in such experiments that the conditions in tests ' a ' and ' c ' for both groups be kept constant. An indispensable aspect of this constancy is the optimal control of the subjects' motives. With this in view the following experiment which may serve as an example was carried out.

3. *An experiment in transfer of manual dexterity.*

The general plan was as described above. The training operation ' b ' was a simple one of manual dexterity in removing and replacing links on spindles. This process gave a satisfactory practice curve. The subjects were trained in it for a fortnight. Tests ' a ' and ' c ' were planned to be as similar as possible to training ' b.' These were given to both trained and control groups of unemployed boys, aged 16–17, who were paid for all tests and training alike on their improvement. By this means the motives were controlled by financial incentives.

4. *Results and Conclusions.*

On the statistical treatment of the data obtained, by the method of comparison of means of the respective groups, it was found that there was no direct evidence of transfer.

5. *The more important experimental work and*

6. *The possible significance of the conclusions* were discussed.

Monday, September 10.

Mr. E. R. Clarke.—*The more refined Analysis of Group Mental Tests.*

The earliest age at which Mental Tests (Binet) can be used has been determined by the age at which speech is reasonably well established, and the age-assignment of the easiest test is $2\frac{1}{2}$ years. Similarly, the use of Group Tests has been limited to children able to conform with a printed paper of instructions, and the use of a pencil for underlining and crossing out, and in the case of the N.I.I.P. No. 34 Group Tests, we find norms of performance for the age of ten years and onwards ; such a situation being clearly more difficult to adjust to than an individual oral questioning by a kindly if somewhat standardised adult. These limits set by the practical testing situation have been considered sufficient, but many errors have been made in diagnosis by the tests when used with ages near the lower age limits of the tests.

A method of statistical analysis has been devised to study the characteristics of the ability to answer the tests as it exists among children, and one feature studied was the variability of this capacity in an unselected group all of the same age. There are statistical methods of evaluating variability, and the ratio of it to the mean attainment of the group (Coef. of variation) was found at each age, 3–14 years for Binet Tests, and 9–18 years for Group Tests. For Binet Tests the ratio was found to decrease during the period 3–6 years from ·5 to ·225, and then remain constant at this value from 6–14. For Group Tests, the nine sub-groups were individually analysed, and in this case the ratio decreased during the period 9–13 years, and then remained constant at values whose mean was ·22 for the period 13–18. The constant ratio is a widely occurring characteristic of biological development, and may be compared to the proportional lengthening out of the field in a long-distance race as the race proceeds. Little heed would have been paid to the initial peculiarities as discovered with Binet Tests, but when the same occurred at a later stage with the Group Tests in results which were so much in accord otherwise as to suggest strongly that both were examining the same mental function, the method of testing was suspected. One is led to believe that superimposed on the ordinary variation of this capacity is another factor of variation which in the case of the Binet Tests from 3–6 years, and of Group Tests from 9–13 years, gradually decreases, and either settles down to a fixed amount or vanishes for later ages.

It is advanced that this extra factor is either an extra emotional reaction called up by the strangeness of the situation to a young child, or is the result of the variation of environmental influences at the initial stages of learning, and which are eliminated as the child later settles down to his real place in the scholastic scheme. Not until after this later stage, which in one case is after six years, and the other after thirteen years, will the strangeness of the situation, or the lack of settlement of the speaking

and reading essentials be sufficiently overcome to permit the free play of the child's intelligence on the problem in hand, and thus only after these ages can the tests be used as sound diagnostic technique. It is not so much advanced that these difficulties have been newly discovered, as practice—and rehearsal—testing have already been introduced, but that the analysis has shown the exact limits of soundness, and the exact nature and magnitude of the difficulty that does exist at early stages of testing.

Mr. E. Farmer.—*The Intercorrelations of Psychological Tests, with Special reference to Group Factors.*

Joint Discussion with Section F (*q.v.*) on *The Present Position of Skill in Industry.*

Afternoon.

Dr. S. Dawson.—*Dullness and Disease.*

It seems to be fairly well established that the intelligence-ratios of children as measured by modern schemes of tests normally remain approximately constant, at any rate, until adolescence, but we still know very little about the effects of specific conditions on this ratio. An enquiry into the intelligence of sick children, which was begun by the late Dr. H. J. Watt, of the Psychological Laboratory of the University of Glasgow, and has been going on for the last six years, has thrown some light on this question. By comparing the average intelligence-ratios of groups of children suffering from various ailments (1) with those of their brothers and sisters, and (2) with those of the same patients either after recovery or at a later stage in their illness, it has been found that most ailments have little or no appreciable effect on intelligence, but that some, *e.g.* encephalitis lethargica and epilepsy, not only are associated with mental subnormality, but actually produce it.

Dr. R. D. Gillespie.—*Relation of Size of Family to Psycho-neuroses.*

It has been shown by Havelock Ellis in his 'Genetic Study of British Genius,' that the eldest and the youngest members of a family are more apt than the intermediate members to be intellectually distinguished; on the other hand, pronounced mental defect, *i.e.* imbecility and idiocy, also affects the eldest (Still) and the youngest (Sir A. Mitchell) more frequently. Similarly, a group of psychoneurotics (persons suffering from 'functional mental disorders') has been found to be composed of a disproportionately large number of eldest and youngest members of families, after correction for discrepancies in the numbers falling into each position in the family. Only children were not exceptionally numerous among them, contrary to the general belief, being only 5 per cent. of the group. This coincides with the result of Stuart's investigation into the temperament and character of only children among college students. The psychoneurotic persons in question frequently came from unusually large families, and the average size of family from which they sprang was five; while individuals of the group who had married and had reached the age of forty, had families of an average size of only 1·6. The latter figure is about the average size of family in the upper and middle classes of the population as a whole at the present day, for marriages which have existed for ten years; which suggests that psychoneurotic persons as a class are tending to infertility, but not to an extent greater than the general population of the same social strata.

The data given for psychoneurotics refer to surviving children only. For this and other reasons the effects of place in family in producing psychoneuroses are presumably psychological. It has been suggested that the predominance of eldest children among psychoneurotics depends on the largely experimental nature of their upbringing by inexperienced parents; but this seems to be contradicted by the comparative infrequency of only children among 'nervous' adults. It is more likely that the specially favoured positions of eldest and youngest are fraught with danger from their psychological relation to the other members.

Dr. D. N. Buchanan.—*Hypnotism.*

Mr. A. J. D. Lothian.—*The Rhyme-structure of 'Paradise Lost,' a Study in Unwitting Habit.*

In his preface to 'Paradise Lost' Milton abjures the 'jingling sound of like endings' as neither necessary nor ornamental; and yet his poem is studded with rhymes or inlaid rhymes, *e.g.* disoBEDiENce, EDEN, SEED In, or quasi-rhymes, *e.g.* REGAIN, SEAT, PEAK, SEED, in which the vowel sounds coincide although the consonants vary.

In poems published three years and four years later, viz. in Diana's Prophecy (History of Britain), and in Samson Agonistes, e.g. from l. 1669, we find the quasi-rhymes adopted as a conscious system.

The psychological explanation of Milton's apparent inconsistency is that the system was at first probably unwitting, a survival of normal poetic composition. The rhythm of poetry has something of the dissociating effect whose culmination is found in hypnosis; it helps the poet to unconscious creation and makes the listener more suggestible, conserving rapport. The listener further comes to accept the recurring sounds referred to above as fit or 'inevitable' words. They rouse processes ready to discharge and procure assent. Citations were given from the introspection of poets and sound charts provided.

Tuesday, September 11.

Dr. R. H. Thouless.—*Sensations and Step-experiences.*

The statement that the step between a pair of adjacent stimuli A, B appeared equal to the step between the pair B, C was regarded by Fechner as a judgment that $S_a - S_b = S_b - S_c$ (if S_a, S_b, S_c are the sensations produced by A, B, C respectively). This assumption of absolute magnitudes of sensation which may be subtracted from one another is not, however, essential to Fechner's Law, which may be stated without it (Ebbinghaus, for example, stated the same fact by referring to the equality of two sense distances). Fechner's statement is objectionable because he treats the S_b on one side of the equation as equal to that on the other, although, in fact, the sensation received from B when adjacent to A is quantitatively different from that received from B when adjacent to C. Much of the current treatment of contrast seems to be vitiated by the same implicit assumption that there is an absolute magnitude of the sensation produced by a stimulus of particular intensity which under different conditions of background may be magnified or diminished by the influence of contrast. A preferable way of treating the matter would seem to be one that discarded both the conceptions of absolute magnitude of sensation and of 'contrast,' and recognised simply that the magnitude of a sensation is not a function only of the intensity of the stimulus producing it, but also of the intensities of surrounding stimuli and of the preceding stimuli (*i.e.* that it is a function also of the spatio-temporal background). This means that what corresponds to a particular stimulus intensity is not a particular sensation magnitude but a particular class of sensation magnitudes.

In order to deal with the fundamental statement of Fechner's Law (that the above relationship of equality holds when $A/B = B/C$) on a hypothesis which has discarded the absolute sensation magnitude, it is necessary to replace the conception of equality of the differences between sensations by that of equality in magnitude of the experiences given by the pair of stimuli A, B and the pair B, C. Such experiences given by pairs of stimuli we shall call 'step-experiences.' The statement that two step-experiences are seen as equal is as straightforward a report of immediate experience as that two sensations are experienced as equal.

We are not justified, however, in attributing to the step-experience the absoluteness of magnitude which we have rejected as an attribute of the sensation. Experiment shows that both are relative in the same sense. Two pairs of stimuli which give equal step-experiences under the same conditions of background may give unequal step-experiences when their backgrounds are different (this has been proved only for spatial backgrounds, but we may safely surmise that it is true also for temporal background). Just as in the case of a single stimulus and its sensation, so, corresponding to a given pair of stimuli, there is not a single magnitude of step-experience but a class of step-experiences of different magnitudes. The particular magnitude of step-experience which will be produced by a particular pair of stimuli will depend not only on the relative intensities of those stimuli but also on their spatio-temporal

background. A full statement of the fundamental relationship of Fechner's Law must therefore be that if A/B=B/C, then the step-experiences from A, B and B, C will be equal if both are observed under the same conditions of spatio-temporal background.

Dr. Ll. Wynn Jones.—*Individual Differences in Mental Inertia.*

Mr. G. G. Campion.—*Meaning and Error.*

In the problem of meaning and error, epistemology, logic, psychology and etymology all find an inevitable point of contact.

The conclusions reached in this paper are:

(1) That the mental symbols of which our knowledge is composed must in any system of genetic psychology be regarded as subject to a growth process in the several and successive ontogenetic phases of the individual mind.

(2) That these living and growing mental symbols are severally denoted by relatively stable and static word symbols which the logicians call 'terms.'

(3) That the living and growing mental symbols (which have variously been called ideas, concepts, presentations, representations, images, &c.) are the 'meanings' which the slowly interacting and cumulative influence of etymology, logic, usage and tradition have attached to the terms which severally denote them.

(4) That the organic growth with structural differentiation which takes place in these mental symbols is the psychological aspect of what in logic is termed 'analysis.'

(5) That these growing symbols are ineradicably subjective and permeated with error, this error becoming greater as the symbols tend to vary from the cultivated and accepted usage of the terms employed to denote them.

(6) That such erroneous mental symbols may be gradually linked into groups and become finally rationalised into obsessions.

(7) That to regard knowledge as an integrated aggregation of such living and growing subjective symbols goes far to provide us with a psychological theory of knowledge wide enough to embrace the whole universe of human error, human illusion and human self-deception.

(8) That this view of knowledge can be shown to be congruous with observed phenomena of the neural basis of our minds, the cerebro-spinal nervous system.[1]

Mr. J. T. Bradley.—*A Psychological Theory of Error.*

For epistemologists error probably presents an insoluble problem; and logicians are mainly interested in classifying errors of reasoning. It remains for psychologists to examine the mental processes from which errors emerge. Spearman and Freud, particularly, have indicated valuable lines of approach to this problem.

Errors are due to inadequate insight and mental bias. They are items that persist by virtue of retentivity and they intrude where items generated by noetic processes should have place. The superior intensity which favours the intrusion is due to habit, which makes a relatively slight demand upon mental energy, or objective conditions (*e.g.* vividness, recency, position). Narrowness of mental span, limitations of 'g,' speed of apprehension, fatigue, distraction, absence of relevant knowledge and insufficient conation account for the low intensity of the displaced item. The displacement may be partial or entire. Between the intruder and the ousted item a relation of likeness exists (*e.g.* likeness of meaning, form, position or unity).

Experiments have been performed by the writer of this paper to see what errors were made when sentences, specially constructed and presented under various conditions, were reproduced, immediately and after various intervals of time. The results so obtained led to a further experiment, in which specially selected words were woven according to a definite pattern into paragraphs that varied in their degree of unity. Immediate and deferred reproduction of the special words was sought by the completion method.

The errors produced by these experiments indicated that convergence from specific to general connotation, and repetition were their most potent causes. Degree of

[1] Campion, G. G.—To appear in *Brit. Journ. Philosoph. Studies. Cf.* 'Elements in Thought and Emotion,' 'The Organic Growth of the Concept as one of the Factors in Intelligence,' *Brit. Journ. Psychol.*, July 1928, 'The Neural Sub-strata of Reflective Thought,' *Brit. Journ. Med. Psychol.*, vol. v, pt. 2, 1925.

unity and spatial and temporal ‘ distance ’ were less potent. Errors occurred more frequently where adjectives and adverbs were used than where nouns and verbs were used.

Since errors emerge from the normal workings of the mind, we cannot hope to develop the art of eliminating them. Nevertheless some remedial measures, which would decrease their frequency, are possible. They are :

(*a*) Effort to strengthen those relations which are likely to suffer most by convergence and confluence.

(*b*) Periodic repetition of knowledge which should be exact ; such repetition will counteract the effects of convergence.

(*c*) Inhibition of associated intruders, to allow the noegenetic powers of the mind to apprehend the relevant facts, educe the most significant relations between those facts, and produce the required correlates.

Afternoon.

Visit to Engineering Works of Messrs. Mavor and Coulson.

Dr. H. D. J. White.—*An Enquiry into the Discrepancies between Mental Tests and Examination Tests of University Students.*

Miss M. Drummond.—*A Theory of Infantile Experience.*

That increasing importance is being attached to infantile experience as a factor in the formation of personality is shown by the attention devoted to it by the Freudian School, by the Gestalt School, and others. At birth the infant enters a world of persons and of objects. His instinctive interest is drawn first to the former, but at a very early age he feels the distinctively human need to introduce unity and coherence into the latter. The insistence of the followers of Freud on the pleasure principle as the key to the child's early attitude to the world leads them almost entirely to neglect the intellectual aspect of the child's development. In the course of his realisation of the laws of time, space and matter the infant forms theories which are in themselves plausible, although to us because of our long experience they often seem absurd. These theories are implicit in the child's early experimentation, and must be looked for there. Some of these scientific hypotheses are less easily dropped than others because they gratify the sense of power. Rational appreciation of facts is thus delayed, sometimes for many years, by the working of the pleasure principle. It is the child's ignorance that renders theories satisfactory to him which are not only unsatisfactory but inconceivable to us—inconceivable, that is, as living hypotheses. If we allow for his ignorance we see that his intelligence works along the same lines as our own. Close parallels to his thinking are to be found in the thinking of primitive man, *e.g.* attitude to pictures, to places, to life. The child's experience is radically different from ours ; his theories, therefore, are different, and consequently his reality. As the race in its progress towards the scientific standpoint has had to work through and abandon theory after theory, so also has the child.

Miss M. D. Vernon.—*An Experimental Study of Eye-movements, particularly in relation to Reading.*

SECTION K.—BOTANY.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 687.)

Thursday, September 6.

Presidential Address by Prof. Dame Helen Gwynne-Vaughan, D.B.E., D.Sc. [illegible] *and Nutrition in the Fungi.* (See p. 185.)

Prof. F. L. Stevens.—*On the Effects of ultra-violet Light on Fungi, with special reference to Sexual Reproduction.*

In January 1928, while studying the effect of ultra-violet radiation on fungi in agar plate cultures, it was noticed that perithecia were present in large numbers on certain portions of the exposed plates. The fungus was a strain of *Glomerella cingulata*, which had been under close observation for several months, had been originally derived from apples affected with Bitter Rot, and from which a single conidium had been isolated. All cultures secured from this monosporous source had been devoid of perithecia. This same essentially non-sexual strain in all agar cultures exposed to ultra-violet rays of certain intensity and for certain duration has produced perithecia in large numbers. No perithecia have appeared in the non-radiated portions of the cultures. The most striking evidence that the radiation induces perithecial formation was given by projecting the rays through a circular aperture of 0·5 mm. diameter upon a susceptible colony. On this area alone perithecia appeared two days after radiation. In four days asci and spores were formed. The perithecia differ from those normally found in that they are spherical and non-stromatic, but the asci and spores agree with those found in nature. All other strains of *Glomerella* tested have given similar responses to ultra-violet light. It appears certain that ultra-violet rays or others near them greatly accelerate conidial formation in this and other genera of fungi, as for example has been observed to be the case in *Coniothyrium*, which produces numerous pycnidia within a few days under radiation instead of after several weeks as under natural conditions. It is held that direct radiation has resulted in the formation of perithecia deeply buried in the agar, while indirect rays have led to the formation of superficial perithecia. That the effect is not the result of a chemical change produced in the medium by radiation, but is a direct response by the mycelium to radiation, is considered probable by experiments directed to this special question.

Mrs. N. L. Alcock.—*Seed-borne Clover Sickness* (with an introduction by Mr. T. Anderson).

The following matters are discussed:

The importance of quality, health and source of seeds generally.

Clover seed and the country of origin.

A case of *Sclerotinia* disease carried in the seed of New Zealand clover.

The life-history of the fungus isolated from the seed from the resting mycelium to the apothecial stage.

The question of re-infection of various clovers.

The comparative freedom of wild white clover from disease.

Miss M. J. F. Wilson.—*A Comparative Study of Dermatea spp. on Conifers, with some Observations on the Conidial Stages.*

In this investigation an attempt has been made to define the limits of the species by a comparison of morphological and physiological characters. The principal point of distinction between the various fungi is ascospore size, and when a difference in this feature is correlated with differences in the conidial stage and in cultural characters the organisms have been regarded as separate species. A biometric study of spore measurements has been made, and the results up to the present time show that five distinct species exist, only two of which have previously been described. The conidial stage of these fungi is a Myxosporium which produces two types of spore, large oblong conidia and minute rod-shaped bodies which do not germinate. The conidial fructification is at first a closed pycnidium, but later the upper wall breaks down entirely.

Mr. G. G. Hahn.—*Life History Studies of the Species of Phomopsis occurring on Conifers.*

A study of coniferous *Phomopsis* forms which includes all the present known species, as well as undescribed species, has been undertaken to investigate their cultural life-histories. This research has been associated with an investigation of *Phomopsis Pseudotsugae* Wilson, an economically important parasite of the Douglas

fir which, as far as is known, occurs only in Europe. The differentiation of this parasitic species of *Phomopsis* from species and forms closely related became a highly important phytopathological problem.

In general, efforts made to induce the *Phomopsis* forms to produce the perfect stage were unsuccessful. Forms of *Diaporthe pitya* Sacc. on Douglas fir and Sitka spruces were isolated from single ascospores and single asci. These produced in culture either the perfect or imperfect stage, the latter being identical morphologically with forms of a *Phomopsis* species collected on *Taxus, Taxodium, Sequoia, Pinus, Picea, Abies, Tsuga, Larix, Pseudotsuga, Thujopsis, Thuja, Cupressus* and *Juniperus*. Culturally the forms of this species having so wide a host distribution showed close agreement. These forms are all regarded as *Phomopsis occulta* Trav.

The original type specimen of *Diaporthe conorum* (Desm.) Niessl. has been examined. This fungus appears to be identical with the type of *D. occulta*, and with *D. pitya*, both of which may be regarded as synonyms. There are indications of relationships between these conifer forms and similar forms on broad-leaved hosts.

It has been found as a result of the cultural study of *Phomopsis* and *Diaporthe* forms that spore size and shape are quite constant within a given specific range, irrespective of the host substratum. Stroma characters can be affected by host and growth influences.

Miss W. M. Page.—*Spore Discharge in Sordaria and its Allies.*

Spore discharge in several species of the lower *Pyrenomycetes* has been studied.

In species of *Chætomium* the spores are liberated from the asci within the body of the perithecium and, oozing through the neck, become entangled in the hairs. Slight movements of the hairs due to changes in humidity assist in the dispersal of the spores.

Species of *Sordaria, Podospora* and *Philocopra* discharge their spores with considerable energy. In this process the movements of the paraphyses and periphyses take part; the force of ejection and the duration of discharge vary in different species. In several species perithecia with more than one neck have been observed.

Prof. Dame Helen Gwynne-Vaughan and Mrs. H. S. Williamson.—*Heterothallism in Humaria granulata.*

Humaria granulata Quel. is a small orange, coprophilous, discomycetous fungus. Blackman and Fraser described its development in 1906 and reported a single oogonium in each young fruit and no antheridium. The species has now been grown on agar and these observations have been confirmed and extended. *Humaria* fruits readily in mass culture; the spores germinate under natural conditions some eight months after they are shed; their development after five months can be induced by artificial means. In single spore culture all mycelia produce archicarps, but these die and no fruits are developed. Fruiting occurs along the line of junction of suitable mycelia which have proved to be of two kinds (+) and (−). Since both bear female organs the distinction between them is not regarded as sexual.

Afternoon.

Excursion to Glasgow Parks.

Department of Forestry.

Mr. Alex. L. Howard.—*Timber Supplies from within the British Empire.*

Present practices. The comparative merits of various timbers in commercial use. Information as to new woods. Illustrated by forestry and other views.

Mr. M. Y. Orr.—*The Relative Value of Anatomical Characters in the Identification of Conifers, with special reference to Chinese Species in Cultivation.*

Prof. J. H. Priestley.—*The Living Tree: its Increase in Girth.*

Prof. P. Groom.—*The Antiseptic Preservation of Timber.*

Friday, September 7.

Dr. J. Burtt Davy.—*Observations on the Forest Flora of Northern Rhodesia.*

Mr. J. Walton and Mr. R. Koopmans.—*The Preparation of Cellulose Films and their use in making Serial Sections of Coal Ball Plants.*

Miss E. S. Dowding.—*The Sand-hill Areas of Central Alberta.*

Illustration will be given of the distribution of the main sand-hill deposits of Alberta, and the sand-hills of the central area will be considered in detail. These hills were originally washed out from terminal moraines, so that they mark the positions of old drainage courses. The vegetation of such areas is one of sharp extremes depending on the varying water content of the soil. The swamps, bogs and heaths of the sand-hills will be described and reference made to the distribution of the Pine Mistletoe on the hill summits. Some account will also be given of an expedition to the sand-dunes in Jasper National Park, and of the origin and stabilisation of the dunes.

Dr. K. B. Blackburn.—*Chromosomes in some Species of the Caryophyllaceæ.*

Differences in chromosome number, including polyploidy, which occur both within a species and between species will be discussed. The variety of chromosome-form within the group will also be considered.

Dr. E. M. Higgins.—*Types of Reduction division in Stypocaulon and Cladophora.*

Stypocaulon scoparium, Kutz. In view of the recent work on *Pylaiella*, *Ectocarpus* and *Sphacelaria*, an investigation of the cytology of *Stypocaulon scoparium*, Kutz., has been undertaken with special reference to the unilocular sporangia. The diploid chromosome number of 32, as found by Escoyez, has been confirmed.

In the division of the enlarged unilocular sporangial mother-cell, the phenomena of synapsis are clearly shown. The prophase is prolonged, and further stages in the heterotype division have not yet been found. But the reduction of the chromosomes is clearly shown to have taken place throughout all the subsequent divisions in the unilocular sporangia, in which 16 chromosomes have been counted.

Cladophora sp. All stages in division of the diploid nuclei have been studied, and the chromosome number is 24. No continuous spireme is found in the prophase stages, and the individual chromosomes are early differentiated.

In the terminal parts of the filaments, the phenomena of reduction division are manifest, the diakinesis stage being especially marked. In the anaphase of the heterotype division the 12 chromosomes, on moving to the poles, frequently show themselves to be split in readiness for the next division. One homotypic division, showing clearly the reduced number of chromosomes, follows the heterotype division and precedes the differentiation of the spores.

Dr. M. Knight.—*Sexuality in the Ectocarpaceæ.*

The discrepancy in behaviour recorded by various workers for the zoids emergent from the plurilocular sporangia of *Ectocarpus siliculosus* growing in northern waters as compared with those from plants growing in Mediterranean regions has been investigated. It is found to rest upon a cytological basis. It has been established that, in one and the same species in widely separated geographical regions, two distinct types of life-history exist, in one of which the haploid and in the other the diploid stage is the dominant. The subordinant stage shows either restricted development or reduction to a single cell stage.

The relationship of the unilocular and plurilocular sporangia in these two cases is then discussed. Cytological distinction is found to be associated with complete morphological similarity.

The question of relative sexuality as defined and illustrated for *Ectocarpus siliculosus* by Hartmann has been reinvestigated, and his methods have been extended to other members of the group. Data have been collected that add to knowledge of the sexual reactions of the *Ectocarpaceae.*

The facts relative to *Ectocarpus siliculosus* serve as a basis for the wider discussion of the factors underlying unequal numerical occurrence of sexual and asexual generations of algæ in general. The question of the relations between reproductive phase and geographical distribution is raised.

Afternoon.

Prof. A. C. Seward, F.R.S.—*An Exhibition of Reconstructions of the Vegetation of Past Ages.*

Mr. T. M. Harris.—*A Petrified Plant from the Devonian of Australia.*

Description of the well-preserved leafless axes of a Psilophytalean Plant. The axis consists of a broad cortex of three zones and a star-shaped stele composed of a mass of tracheids surrounded by a little phloem. The xylem consists of an inner mass of irregularly arranged tracheids, outside which is a protoxylem, and in some stems a peculiar sort of secondary wood. The tracheids of the protoxylem have scalariform pits ; those of the metaxylem have multiseriate bordered pits.

The plant is considered to be intermediate between *Asteroxylon* and *Cladoxylon.*

Prof. Y. Ogura.—*Some Japanese Mesozoic Plants.*

Prof. F. E. Weiss, F.R.S.—*The Genetics of a Tropeolum mutant.*

The mutant in question was a specimen of *Tropeolum,* which, in place of the normal peltate leaves, bore spathulate leaves often with a pitcher-like formation at the base, which looked as if the normal development of the peltate leaf had been arrested on the adaxial side while the apical portion of the leaf had undergone considerable elongation. Nearer the apex of the shoot the leaves subtending the flowers showed very little of the ascidium formation and were almost spathulate. Compared with the normal foliage of *Tropeolum* the leafstalks were comparatively short and possessed no sensitiveness to contact. Two further peculiarities occurred in the flowers. Firstly, the hair-like fringes characteristic of the anterior petals of *Tropeolum* were either completely absent or only represented by very few lateral outgrowths. Secondly, the flowers proved to be sterile. The pollen was well developed and fertile, but flowers when self-pollinated or crossed, though the ovary underwent some development, produced no fertile seeds. The mutation seemed therefore to affect not only the vegetative leaves but also certain leaves of the flower, namely, the anterior petals and the carpels. Since the pollen seemed to be normal, it was used to pollinate a normal form with differently coloured flowers and was found to be quite fertile, a number of seeds being obtained. In the f^1 generation all plants produced normal leaves, had fringed petals and produced fertile seeds, so that the mutation seemed to be definitely recessive. In the next (f^2) generation Mendelian segregation took place, the three characters showing themselves definitely linked. The mutation was not linked with flower colour. The recessive form showed the recessive leaf-form from the seedling stage, the first leaves being spathulate and very different from the partially peltate seed leaves of the normal Nasturtium. It was noticeable, however, that several of the recessive seedlings showed a tendency to outgrow more or less in the further course of their development the abnormal leaf-form, and produced almost peltate leaves. One of these, which was used for further experiment, proved to be partially fertile, so that, with the diminution of the extent of the mutation, the latter showed itself in both the vegetative and floral organs. The offspring of these forms always showed the abnormal leaf-form in their first leaves, but the further leaves showed the mutational character less strongly, some becoming almost peltate. Towards the end of the season, however, the more spathulate leaves again made their appearance in the small leaves subtending the flowers. The interest, therefore, of this mutation lies firstly in the linkage of characters in three different organs, and secondly in the fact that in some of the extracted recessives the factor causing or

controlling the mutation seems to vary in strength at different periods in the development of the plant. The relationship of this phenomenon to somatic segregation is of interest.

Prof. W. Robinson and Miss P. M. Skrine.—*The Growth and Propagation of some Salt Marsh Fuci.*

The forms dealt with are the ecads *muscoides* (Cotton), *cæspitosus* (Baker and Bohling) and *volubilis* (Turner) of *Fucus vesiculosus.* Individuals of the first two of these ecads may be arranged as a continuous series varying in size and form according to their habitat, but ecad *volubilis* differs from these and may prove to be an ecad of *Fucus spiralis* (L.) (*F. platycarpus,* Thur.).

These ecads are being cultivated successfully in aerated sea-water either with or without the addition of a nutrient solution of salts. Under the cultural conditions the cylindrical ecad *muscoides* has become flattened and has taken on the appearance of ecad *cæspitosus.*

In nature the three forms are found to grow in substrata of different P*h* values, and the experimental work in progress may indicate whether this or more direct nutritional factors determine the morphological differences observed.

As has previously been recorded, the three ecads reproduce vegetatively by means of proliferated branches. The present work has, however, indicated that there are striking differences in the origin and development of the proliferating growths in the different ecads. It is found that the proliferations from ecad *volubilis* are always developed from hair-pits. The branches are produced either singly or in small numbers from the hair-pits, which are found on the margin and on the surface of the thallus. They take their origin in a group of hairs of the hair-pit and develop by the congenital growth of these hairs. An apical cell of the branch is differentiated later, and this continues the growth of the branch.

The origin of the proliferations in the ecads *muscoides* and *cæspitosus* shows no relation to the hair-pits, and in this respect their manner of origin may be compared with that of the proliferations in wounded specimens of a typical *Fucus vesiculosus.*

Suggestions are offered as to the bearing of the origin and development of the proliferating branches, which arise in hair-pits, on the morphology of the hair-pit, and on the more general relations of this to apical development in the *Fucaceæ.*

Dr. R. M. Buchanan.—*The Decay of Stone in Buildings and Monuments: a Biological Problem.*

The decay of stone in buildings and monuments presents a problem of importance to the country on account of the structural damage which it produces and the costly measures which are required to make good its ravages. The process has for long been one of interest to physicists, chemists, architects and craftsmen, and has hitherto been regarded as due to the solvent action of adventitious gases in the atmosphere arising from the combustion of coal or emanating from chemical works. Another aspect of the problem presented itself a considerable time ago when the decay was discovered to present some features characteristic of an infective process. The condition in many respects simulated the progress of a disease and appeared in consequence to justify the designation *Lupus lapidis.* The localisation and distribution of the decay and its prevalence in buildings far removed from the influence of smoke or other atmospheric pollution lent support to this view. Cultural experiments were accordingly undertaken, and micro-organisms were found abundantly in material from the decaying surfaces, the organisms evidently finding the conditions necessary and natural for their growth (reported on in a paper read before the Royal Philosophical Society, Glasgow, November 4, 1904). These earlier cultural tests have been repeated many times in recent years from buildings in different localities with confirmatory results, a distinctive flora tending to appear in each type of decay. Three kinds of organisms—bacilli, yeasts and moulds—were almost always to be found separately or in association in the decaying surface. Attention was specially directed to the investigation of a few of the species which constantly made their appearance in cultures, and which by their production of carbonic acid and sulphuretted hydrogen might justifiably be regarded as concerned in the process of disintegration affecting the stone-work. The operation of biological factors would thus appear to be essential in the process of stone decay in buildings.

Concurrently with above afternoon session :—

Joint Meeting with Sections D (*q.v.*) and I for communications on Experimental Biology.

Department of Forestry.

Dr. T. W. Woodhead.—*The Forests of Europe and their Development in Early Post-glacial Times.*

Our knowledge of the development of forest vegetation in post-glacial times has been considerably extended in recent years as the result of researches in many branches of science, especially by Swedish investigators. De Geer, by a study of the stages of retreat of the ice in the Stockholm region, and of the beautifully laminated clays laid down in a post-glacial fjord, established a geochronology which places the last Ice Age about 11,000 years ago.

A. G. Nathorst, G. Andersson, A. Blytt and R. Sernander have studied the succession of the floras in the post-glacial beds of Sweden, and the two latter have suggested the following climatic periods : arctic ; sub-arctic ; boreal ; atlantic ; sub-boreal and sub-atlantic.

Studies by Brögger, De Geer and Munthe indicated post-glacial oscillations in the Baltic during which characteristic shells were embedded in the littoral deposits, and the dominant ones suggested names for the three successive stages and periods, viz. : the Yoldia period, climate arctic, culminating in a birch period ; the Ancylus period, climate warm, dry, continental, a fir period ; and the Littorina period, climate warm, damp, oceanic, oak period.

Another line of research is that initiated by G. Langerheim and further extended by von Post, G. Erdtman and others. This consists of a statistical study of the tree pollen grains found in peat, and the results are expressed in diagrams which show the depth of the peat in metres ; the frequency of the pollen grains found at different levels is expressed as a percentage of the total tree pollen in the horizontal scale, the different species being indicated by signs. By this method pollen analyses have been made of the microfossils in peat deposits over a wide area in N.W. Europe by Erdtman and others, and many typical areas in the British Isles have thus been investigated.

Attention has also been directed to archæological remains, carefully excavated at the several levels in and below the peat, and these often provide a useful means of dating the plant remains.

Researches in Britain by Clement Reid and others showed that the interglacial flora was much the same as the present one, and recently Wladyslaw Szafer has obtained similar results for Middle Europe from investigations of deposits in six localities in Poland. Here changes were indicated, both in climate and vegetation ; which were closely similar to those enumerated by Swedish investigators for Scandinavia in post-glacial times.

Peat investigations by the pollen statistics method produce results which fall nto line with the above and indicate the following changes in climate and succession in vegetation :—

Arctic : On ground bared by the receding ice, a tundra flora, including many species common on our present moorlands. The first trees to appear were a species of *Salix* and *Betula*. Remains of Palæolithic man.

Sub-arctic : Birch-heath forest becoming invaded by pines from the more southern coniferous belt, remains of both often occur together. In Switzerland and Middle Europe occur *Pinus montana*, *P. cembra*, *Larix* and further north *Picea*. Remains of late Palæolithic and Epi-Palæolithic man.

Boreal : Climate warm, dry, continental. The coniferous forests, with mountain ash and bird cherry, were invaded by elm and oak, which marked the beginning of degeneration of the pine forests. Erdtman contends that hazel was an early and important pioneer in the development of the deciduous forest and suggests that immigration in Britain, from the south-east, was in the following order : *Salix*, *Betula*, *Pinus*, *Corylus*, *Ulmus*, *Quercus*, *Alnus*. During boreal time the deciduous forests in N.W. Europe reached their climax. Up to this time peat was forming in lake and swamp areas and enclosing relics of the arctic flora. Towards the end of

boreal time, and early in the succeeding period, the land connexion of the British Isles with the continent was severed and coincident with this a change of climate. In these deposits are Neolithic remains.

Atlantic: Climate warm, moist, oceanic. Peat period. This change of climate provided conditions for extensive peat formation throughout N.W. Europe, including the British Isles, and had a profound effect on the forest vegetation. Peat developed over extensive upland as well as lowland areas and, invading the forest, eventually destroyed and buried its remains. On the drier, calcareous, and better drained areas unfavourable for peat formation, *e.g.* areas occupied by beech forest, no remains were preserved, and their history is in consequence very incomplete. Thus our present forests are largely relics of this boreal period.

Sub-boreal: Climate warm, dry, continental. A brief recurrence of pine in many parts of northern Europe on drying surface of peat. Late Neolithic and Bronze Age remains.

Sub-atlantic: Climate moist and cold. Renewed peat formation in which are Romano-British remains.

Dr. Marion I. Newbigin.—*Man and the Forests of Europe: the Pre-industrial Period.*

The paper begins by pointing out: (1) that the greater part of the surface of Europe is climatically suited for tree-growth, and was tree-clad till man interfered; (2) that, as compared with similar latitudes in North America and Asia, the number of indigenous, forest-forming tree species is small; (3) that the surface was very largely denuded by man of its original forest cover before timber entered largely into world commerce, that is, before the industrial period; (4) that re-afforestation has been practised on a considerable scale in parts—but in parts only—of the Continent, and that the reconstituted woodlands differ as a rule both in composition and in character from the original forests. These facts are then considered in relation to the land-forms and relief of Europe with the object of showing the ways in which these influenced both the original characters and distribution of the forests, and man's attitude towards them, alike in its destructive and conservative aspects.

Prof. Dudley Stamp.—*The Forests of Europe: the Post-industrial Period.*

Survey of the extent and importance of European forests at the commencement of the industrial period. Changes in the economic importance of forests consequent upon industrialisation. The disappearance of old and the rise of new timber-using industries. The increase in exploitation and the rise in prices considered in the principal countries of Europe. Survey of the European position prior to the Great War. Analysis of the present timber resources, production, consumption and conservation of the leading European States comparatively considered. The prospects of a timber famine.

Mr. J. M. Murray.—*Distribution of Trees in Old Peat Mosses.*

Dr. H. M. Steven.—*The Forest Nursery.*

Saturday, September 8.

Excursion to Benmore Estate.

Excursion to Ben Lui.

Monday, September 10.

Mr. J. Walton.—*On the Roots of some Species of Equisetum.*

Several of the earlier investigators of the genus Equisetum have remarked on the presence of large as well as the better-known small, fibrous roots on the rhizomes of *Equisetum limosum.*

These large roots grow down vertically from the rhizome and may be as much as 5 mm. in thickness and more than a metre long.

The small roots are given out in all directions at right angles to the axis of the rhizome. The large roots have an extensive lacunar cortex, and sometimes a hexarch stele, and are exceedingly like the roots of some Calamites except that there is no secondary thickening. There is, however, no sharp dimorphism, as roots intermediate in size between the large roots and the small are found. Like all the other roots on the adult plant of Equisetum, they arise in relation to a bud in the base of the leaf sheath. Where the root connects on to the bud the vascular tissue is in the form of a solenostele with a central core of sclerenchyma which is continuous with sclerenchyma developed on the inner side of the vascular bundles of the stem at the node. Large roots of a similar type have also been observed in *Equisetum maximum*, *E. sylvaticum* and *E. arvense*.

Prof. J. McLean Thompson.—*On the Use of Vascular Anatomy in Problems of Carpel Morphology.*

In recent years facts of vascular anatomy have been largely advanced in argument on the history of the Angiospermic carpel.

An attempt will be made to show that the carpellary vascular system is variable even in a single species, and that it may be regarded rather as expressive of the present state of the carpel than as evidence of past stages in organisation. The points raised will be illustrated by reference to the development and adult structure of the legume.

Discussion on *The Size Factor in Plant Morphology.* (Prof. F. O. Bower. F.R.S.; Dr. G. P. Bidder; Prof. V. H. Blackman, F.R.S.; Prof, H. H. Dixon, F.R.S.; Prof. J. H. Priestley; Prof. A. C. Seward, F.R.S.; Dr. H. Hamshaw Thomas; Prof. D'Arcy Thompson, C.B., F.R.S.)

Prof. F. O. Bower, F.R.S.—The principle of similarity has been applied freely in the study of the animal body. Botanists have been slower in applying it to plants, and then chiefly in the mechanical aspect. But the relationship of the principle to physiological interchange commands a wider interest, since this is conducted through limiting surfaces, external or internal. With increasing size, if the form be unchanged, each limiting surface will increase only as the square, while the enclosed bulk will increase as the cube of the linear dimensions. It may be assumed that, provided the surface be uninterrupted and its character remains the same, such interchange will be proportionate to the area of the surface involved. Accordingly in an enlarging body, if the original form be maintained, a practical size-limit will constantly be approached in respect of any tissue that is physiologically active, beyond which its surface would be insufficient to meet the demand for transit. But any change from a simple form which makes the surface more complex increases the proportion of surface to bulk. Increasing complexity of form may thus be held *prima facie* as a concession to physiological requirement in a growing organism. The size-factor which favours such results is naturally only one among many that have influenced form. Nevertheless a recognition of the morphological results which do, in point of fact, accord with the demands of increasing size, should help to make morphology a rational study.

In the primary construction of any ordinary vascular plant there are three limiting surfaces of special physiological importance: (1) *the outer contour*, complicated though its study is in sub-aerial plants by stomatal perforations and by cuticular development; (2) *the endodermal sheath*, which delimits the primary conducting tracts from the enveloping tissues; and (3) *the collective surface by which the dead tracheal system faces upon the living cells that embed it.* Each of these is a surface of physiological transit, suitable for study from the point of view of the proportion of surface to bulk as the size increases.

The illustrations to be submitted will relate to (3), and chiefly to primary vascular structure as seen in primitive plants. Here the common form of axis is conical, enlarging upwards; and the conducting system expands with the axis. The xylem-tract at first consists of a solid core, surrounded by living cells, The methods of

increase in the limiting surface are: (*a*) *intrusion* of living cells into the tracheidal tract; (*b*) *medullation*, i.e. replacement of tracheides by living pith-cells; (*c*) *stellation*, or fluting of the surface; (*d*) various combinations of these leading to *segregation* of the xylem-tract into parts. The enveloping tissues, and often the endodermis as well, follow the sculpturing of the xylem, leading towards segregation of whole vascular tracts. The result is an intimate relation of conducting and parenchymatous tissues, such that as a rule each tracheid abuts at some point on a living cell. This is in itself a derivative state; it is, however, normal in all secondary wood, by reason of medullary rays with or without wood-parenchyma. Accordingly the physiological incidence of the size-factor is automatically met where secondary conducting tissues follow on the primary structure. The discussion of (1) and (2) is left to the hands of other speakers.

Afternoon.

Joint Discussion with Section D on *A Biological Investigation of British Fresh Waters.* (Prof. F. E. Fritsch; Mr. R. Gurney; Mr. J. Omer Cooper; Prof. D. Ellis; Dr. B. M. Griffiths; Miss P. M. Jenkin; Mr. J. L. Sager; Mr. J. T. Saunders; Mr. A. Malins Smith.)

Prof. F. E. Fritsch.—In spite of the large area of fresh waters in the British Isles, very few investigations of their biology are being undertaken. Of our many streams and of the big stretches of the Broads very little is known in this respect. During the early years of this century the Wests had laid the foundations for a detailed study of British lakes, but this work, though it has proved to be fundamental, has not been pursued to an extent at all comparable with the promising nature of the initial results. In fact, many aspects of limnology are altogether neglected in this country, and this applies even to the phytoplankton, which has received most attention. On the other hand, on the Continent and in the United States of America, a host of workers are dealing with the more or less self-contained biotic systems that are constituted by lakes. A number of lake-types (oligotrophic, eutrophic, dystrophic), characterised by their fauna and flora and the general physical conditions, have been distinguished, and these are evidently represented also in Great Britain, where a study of the transitional types seems likely to be of special interest. Fresh-water habitats in part present analogous problems to those encountered in the sea, and a more intensive investigation of British fresh waters will no doubt help in the solution of problems of marine biology. There is also a possible economic bearing in relation to fresh-water fisheries. Great Britain lacks a fresh-water biological station, comparable to that of Plön in Germany and Linz in Austria, but, in order to initiate and stimulate limnological investigations, such a station has become an urgent necessity. Opinions will differ as to the most suitable site and the source of the necessary funds, but there will be general agreement that such a station is wanted.

Mr. R. W. Butcher.—*A Method of Studying the Diatoms of Streams and some of the Results obtained.*

Mr. N. W. Barritt.—*The Growth and Nutrition of Cotton Seed Hairs.*

It is generally assumed that cotton hairs in growing out from the epidermis of the seed coat obtain their food supply from within the seed.

Evidence has now been obtained to show that this is possible only during the first thirty days of growth, and that during the remaining twenty days required for secondary thickening the food supply can only be obtained from the cavity of the boll or capsule.

This theory is discussed in relation to the occurrence of branched hairs, insect attack, and subsequent spinning quality of the lint.

Department of Forestry.

Dr. J. D. Sutherland, C.B.E.—*Deer Forests: Percentage plantable.*

A short history of the origin of deer forests, of their uses and attributes past and present. An examination of their condition and of the possibilities of utilising such

areas for afforestation. A suggestion that the time has come when land assigned for the preservation of red deer and for stalking should no longer be designed 'forest' as it is misleading.

Dr. W. G. Smith.—*Bracken and Heather Moorland.*

These may be regarded as a heritage of former forest, the bracken replacing parts of deciduous woods, the heather, &c., representing pine forest. The forest was dominated by trees, but on their removal sub-dominant species, in the absence of shade, may become stronger and with a wider distribution.

Two types of bracken may be recognised :—

(*a*) Dense tall bracken that allows few plants below its shade ;

(*b*) Open bracken, where an undergrowth of grasses, heather, &c., can survive.

Bracken indicates the deeper soils, and tends to follow the distribution of springs and seeps where ground water emerges to the surface. Depth of soil is necessary to protect the rhizomes from frost, &c. On soils wet all winter and spring, with some clay and deficient aeration, bracken is replaced by rushes and sedges. The other extreme, soil-dryness, also limits its range. This is seen on shallow soils over rock, or where the grass turf is thick, and where bracken on the deeper soils of slopes gives place to heather or blaeberry on the flatter tops.

A single bracken plant may cover many square yards, and consists of deeper rhizomes (down to 2 ft.) with few buds. The fronds arise from thinner superficial branches that grow up towards the surface.

Eradication. Annual cutting of fronds leads to depletion of reserve food-supply of the deeper rhizomes. Experiments (the Edinburgh College of Agriculture) indicate that the better results are obtained by :—

(*a*) One cutting about July 1 (fronds about 9 weeks old) ;

(*b*) An early cutting of young fronds, about 4 weeks, followed by another at 9 weeks.

One early cutting only removes the earlier unfolded fronds, and is followed by a strong crop of later fronds, sufficient to build up food supplies for the future. The crop of the first year after cutting shows little effect, but considerable reduction may be expected in the second and third years. The thicker rhizomes become shrunk and considerable lengths die, hence a single large plant becomes broken up into detached clumps, which, being nearer the surface, should be more exposed to treatment. After three years' cutting numerous buds are still present, though small and starved, hence the possibility of bracken re-establishing itself.

Sprays, iron sulphate, &c., may kill the present crop of fronds, but no substance has been proved to reach the deeper rhizomes.

Dry dressing with sodium chlorate, recently tested, killed the fronds, but no results are yet available as to effect on deeper rhizomes.

Sheep may be induced to nibble and trample young unfolding fronds by a dressing of ground rock salt in May.

Heather Moorland for Forestry.

The heather plant association may occur on three types of soil :—

(*a*) Ling (*Calluna vulgaris*) favours a humus soil, the humus being derived from former forest, or from decay of ling. If burned at short intervals, return is rapid both from seedlings and root stocks, and growth is strong.

(*b*) Scroggy heather, of ling frequently with purple bell-heath, follows harder soils with less depth and moisture. The ling remains short, and frequently the return after burning is slow.

(*c*) Peat heather occurs on drained parts of true deep peat deposits, frequently with pink bell-heath and blaeberry. Return is rapid after burning.

The displacement of heather by moor mat-grass (*Nardus*) and blow-grass (*Molinia*) is a serious menace to forestry, grazing and game. Both grasses are extending at expense of heather. This is due in part to intensive grazing by sheep, which eat out the heather. Defective burning when heather is too old leads to slow return, but the grasses are little affected, reappear in a few weeks, and continue to spread before the heather is strong enough to suppress them.

Mr. R. NEIL CHRYSTAL.—*Biological Studies on two Parasites of the Sirex Woodwasps* (Hymenoptera-Siricidæ).

The Sirex wood wasps are well known in Europe and America as borers in the wood of coniferous trees (pine, spruce, larch, silver fir, &c.), and they have recently appeared in the young coniferous plantations of New Zealand, where their activities have occasioned some alarm. An attempt is now being made by the Imperial Bureau of Entomology to collect and export to New Zealand the parasites of these insects, and the author has collaborated with the Bureau in this work during the past year. Preliminary biological studies of the principal species of wood wasps and their parasites in Britain have been made, and this paper deals with some of the results obtained. There are two common species of wood wasp in Britain, *Sirex gigas* L., the large black and yellow species, and *Sirex cyaneus* Fabr., one of the steel-blue species, of which another species, *Sirex juvencus* L., is said to be the commonest form occurring in New Zealand. There are two important parasites of Sirex in Britain, *Rhyssa persuasoria* L., one of the largest of the Ichneumonid parasites, and *Ibalia leucospoides* Hochenwarth, one of the parasitic species belonging to the Cynipidæ, a family in which most of the species are phytophagous in habit.

The biology of *Rhyssa persuasoria* L. has already been studied in some detail by previous European workers, and the studies of Riley in America on an allied species *Thalessa Lunator* Fabr., also a Siricid parasite, should be mentioned. The biological studies dealt with in this paper concern the oviposition habits, upon which some interesting new data have been collected.

Ibalia leucospoides Hochenw., the Cynipid parasite, although long known to be associated with *Sirex*, has always been considered a very rare species both in Britain and on the Continent, and its biology has remained obscure. This has now been very largely unravelled during the present work, and the details afford an interesting counterpart to those of the larger Ichneumonid. The main features of the life cycle can be briefly stated as follows: the oviposition takes place in the egg tunnel of the Sirex, and the eggs are laid within the larva either before it has emerged from the egg shell or just immediately after. This stands in sharp contrast to the habit of Rhyssa, whose eggs are laid on the body of the Sirex larva, on which it feeds externally throughout its life; whereas the Ibalia spends most of its life as an internal parasite.

The larval stages in both parasites show marked 'Hypermetamorphosis,' but with considerable divergence in form between the two, as was to be expected. A comparison between the two types throws an interesting light upon the question of adaptation of the morphological structure to environment.

The larval life cycle differs in length in the two forms, and in Ibalia the specialised method by which oviposition is accomplished renders its period of activity somewhat more restricted. At present it is thought that this parasite may confine its attentions to *S. cyaneus* alone in this country.

In conclusion, the biological studies on the two parasites have shown that the technique required for their successful transmission to New Zealand and their subsequent treatment there may have to be somewhat different in the two species, and that in the case of Ibalia an accurate knowledge of the season and duration of the Sirex oviposition period in New Zealand will play a large part in the success attending its introduction.

AFTERNOON.

Excursion to view Loch Katrine Afforestation Scheme.

Tuesday, September 11.

Discussion on *The Interpretation of Growth Curves*. (Mr. G. E. BRIGGS, Dr. F. G. GREGORY; Dr. F. F. BLACKMAN, F.R.S.; Prof. V. H. BLACKMAN, F.R.S.; Dr. R. A. FISHER; Dr. W. H. PEARSALL.)

Prof. H. H. DIXON, F.R.S.—*On the Transport of Organic Substances in Plants.*

Mr. J. C. Waller.—*Towards an Interpretation of Photo-electric Currents in Leaves.*

Oxidation is generally regarded as an increase of positive charge, reduction as the converse.

From this point of view the fluctuations of alternating positive and negative electrical potential which occur in leaves as a result of illumination may be regarded as indicating a predominance of reduction or of oxidation respectively.

In the following schema the photo-electric currents of the leaf fall into their place as an incident or phase characteristic alike of photosynthetic and respiratory processes.

Oxidation, towards CO_2, accompanied by negative photo-electric current.	$\leftarrow$(Acid)$\rightarrow$	Reduction towards carbohydrate, accompanied by positive photo-electric current.

The subsidence of the fluctuations of potential during prolonged illumination is explicable by the establishment of a regime in which reduction and oxidation of acid equalise each other. The subsidence of the after-effect of illumination may be similarly explained.

The following observed facts are in consonance with the theory :

1. In absence of oxygen the *negative* current is rapidly abolished.

2. A leaf tested in the morning (or after being kept in darkness for some time), *i.e.* a leaf which may be regarded as charged with acid, shows a greatly augmented *positive* current.

3. The presence of atmospheric CO_2 tends to act in the same manner as previous keeping of the leaf in darkness, but the effect is less marked.

Prof. H. H. Dixon, F.R.S., and Mr. T. A. Bennett Clark.—*The Influence of Temperature on Response to Electrical Stimulation.*

The evidence is discussed for the belief that a sudden change in the electrical conductivity of a tissue is due to a proportionate change in the permeability of the constituent protoplasts to ions. The passage of an alternating current of sufficient voltage through a tissue causes a change in permeability which is the resultant of two reactions which tend to raise and lower the permeability respectively ; positive reactions exceed the negative when the duration is short ; when the duration is long the negative are greater. The position of the neutral point where both reactions are equal in magnitude affords a measure of the sensitivity.

Results are given which show the enormous decrease in sensitivity during the winter months ; during a period of rapid change the sensitivity may be halved in one week.

This change is independent of the effect of temperature on the sensitivity which may be illustrated by one from many results :

Stimuli of 200 volts applied for 0·15 secs. on January 1–7 gave the following responses : at 0° C. +14 per cent. : at 8·5° C. 0 per cent. ; at 20° C. −13 per cent. ; at 30° C. −48 per cent. ; at 40° C. −78 per cent. Similar stimuli for 0·05 secs. gave responses at 0° C. +5 per cent. ; at 8·5° C. +6 per cent. ; at 20° C. +7 per cent. ; at 30° C. −1 per cent. ; at 40° C. −32 per cent. Raising the temperature from 0° C. causes a given stimulus to evoke less negative responses, the maximum positivity (of which the numerical value is determined also by the duration of stimulus) being attained between 8° C. and 20° C. ; further rise in temperature causes the same stimulus to evoke larger and larger negative responses. It is suggested that the hyper-sensitive state obtaining above 45° C. is the primary cause of the breakdown of the semi-permeability at these temperatures.

It is seen that the temperature has as great a controlling influence on the magnitude of the responses as have the duration and intensity of the stimulus. Stimuli at the same voltage, temperature, season and duration are found to evoke the same response from *Hedera* leaves of high and low resistance ; the relation between the effective energy and the expended energy is discussed.

Afternoon.

Mr. C. T. Ingold.—*The pH and Buffers of the Potato Tuber.*

The *p*H of the potato sap varies from *p*H 5·6 to *p*H 6·2.

The buffering of the sap is expressed by the buffer index, which is the number of gram molecules of acid or alkali that must be added to a litre to give a shift of *p*H of unity.

The buffering increases markedly on the acid side of the *p*H of the expressed sap. Thus in a particular case the buffer index from *p*H 4 to *p*H 5 was 0·026 ; from *p*H 5 to *p*H 6, 0·010, and from *p*H 6 to *p*H 7, 0·008.

The buffer action in the potato sap is the result of several buffer systems. Those so far isolated are :—

1. Inorganic phosphates—active above *p*H 5·6.
2. Citrate—active below *p*H 7 and increasingly effective up to *p*H 4—5.
3. Ether—soluble acids.

The relative importance of these buffers in potato sap is roughly as follows :

Range *p*H 6 to *p*H 7. Phosphates account for 30-40 per cent. of the buffer index ; citrates for 20 per cent.

Range *p*H 5 to *p*H 6. Phosphates account for 10 per cent. ; citrates for 40 per cent. ; and ether soluble acids for 50 per cent.

Range *p*H 4 to *p*H 5. Phosphates account for 1 per cent. ; citrates for 20 per cent. ; and ether soluble acids for 50 per cent.

The protein and asparagin in the sap have a negligible effect on the buffering.

The *p*H of the sap is not greatly affected by being in equilibrium with high concentrations of CO_2 such as may occur (20 per cent.) in the intercellular spaces of the tuber, but this percentage does definitely alter the *p*H to the extent of 0·3 to 0·4.

Miss M. T. Martin and Miss M. A. Westbrook.—*The Reaction of the Epidermis of Pulmonaria Leaves to Ultra-violet Light.*

In the course of experiments on the effects of ultra-violet radiation on plants, it was found that the plant surfaces exposed to the radiation frequently became browned, the brown areas corresponding to regions where the epidermal cells were killed and had collapsed. In the present investigation this epidermal collapse has been investigated in some detail, using a variety of plants. Special attention has been paid to the following points :

1. The duration of the '*Latent period*,' i.e. the time elapsing between the end of the dose and the appearance of browning.
2. The relation of the latent period to the dose given.
3. The temperature relations of the reactions involved.

Comparison is made with the sunburning of the human epidermis, where a reaction is produced after a definite latent period varying with the dose given, and dependent to a large extent on temperature.

Dr. Winifred E. Brenchley.—*The Phosphorus Requirements of Barley at Different Stages of Growth.*

The requirement of plants for the various essential nutrient elements vary considerably at different periods of growth, and it has been suggested that the absence of certain nutrients during particular phases may be beneficial rather than detrimental. The correlation between phosphate supply and the growth of barley is being worked out in water culture, and it is clearly evident that the provision of phosphate during the first few weeks is absolutely necessary for complete development. With late sown barley the with-holding of phosphate for the first few weeks entirely inhibited ear production, though tiller formation was not affected, and longer periods of initial deprivation steadily depressed growth in all respects. On the other hand, the provision of phosphate for the first six weeks only, during the period that tillering became established, sufficed for maximum growth and yield, but there were no indications of improved growth due to the absence of phosphate late in life.

The amount of phosphate absorbed by the plant increased steadily in more or less direct proportion to the length of time phosphate was given at the beginning of growth, but sufficient was taken up in the first six weeks to enable the plant to make its maximum dry weight.

The absence of phosphate supply up to the first six weeks of growth caused an extremely rapid drop in the amount ultimately taken up by the plant, after which a more gradual decrease occurred with lengthening periods of phosphate deprivation.

Experiments now under way (June 6) are already indicating that the time of sowing plays an important part in determining the effect of the initial presence or absence of phosphate upon growth, and the results of this current work will be available for presentation at the meeting.

Mr. J. Parkin.—*The two Laburnums: a Problem in Water Loss.*

The leaves of the common Laburnum (*Laburnum vulgare*) wilt and dry up considerably more rapidly than those of the so-called Scotch Laburnum (*Laburnum alpinum*). This behaviour is contrary to what might have been expected from structural characters. The leaves of *Laburnum vulgare* are pubescent, while those of *Laburnum alpinum* are glabrous. Anatomically the leaf of *Laburnum alpinum* is on the whole more mesophytic, e.g. it has wavy epidermal walls and a less pronounced palisade tissue. The difference in rate of water-loss appears then difficult to explain on structural grounds, and stomatal behaviour does not seem to offer a solution. The explanation is probably more deep-seated and of a biochemical rather than of a morphological nature. The difference is, however, in harmony with habitat. *Laburnum alpinum* occupies a higher level in the mountains of Central Europe than *Laburnum vulgare*, and so presumably is exposed to drier conditions.

Sir John Stirling-Maxwell, Bt.—Lecture (semi-popular) on *Forestry in Scotland, Past, Present, and Future.*

Department of Forestry.

Dr. R. C. Fisher.—*Recent Work on Insects Injurious to Timber.*

The Forest Products Research Laboratory, Princes Risborough, has been conducting since December 1925 an investigation into the losses caused by insects to timber in store. During the past 2½ years attention has been paid particularly to *Lyctus* Powder-post beetles (family *Lyctidæ*), which are causing serious losses to the furniture trade and other industries using quantities of oak, ash, walnut and other hardwood timbers with large pores. It has been shown that three species of *Lyctus* have been, and still are being, brought into this country in American oak and ash of low grade. A successful means of sterilising infested timber has been demonstrated, and a study has been made of the conditions in timber which render it liable to *Lyctus* attack.

The work of the Entomology Section of this laboratory also comprises a study of two well-known insects injurious to timber—the Death-Watch beetle, *Xestobium rufo-villosum*, attacking structural timbers, and the Common Furniture beetle, *Anobium punctatum*, which causes damage to old furniture (family *Anobiidæ*). In the past more attention has been given to methods of control and eradication of these wood-destroying insects by means of insecticides than to their biology, life-cycle, habits and rate of development under varying conditions, of which very little is known. Work is now in progress at the Forest Products Research Laboratory to study the bionomics of *Xestobium rufo-villosum* and of *Anobium punctatum*, to ascertain the effect of varying temperatures and humidities on the length of the life-cycle of both species, and to determine whether there exists any relationship between fungal infection of timber and progress of Anobiid attacks. The settling of these points may have high practical value and a very important bearing on the planning and ventilation of houses and other buildings.

Dr. E. J. Salisbury.—*Principles of Ecology with special reference to Soil.*

Afternoon.

Joint Discussion with Section M on *The Economic Balance of Agriculture and Forestry.* (Dr. J. D. Sutherland, C.B.E.)

Dr. J. D. Sutherland.—The disproportion disclosed between the areas assigned to agriculture and those utilised for sylviculture within the United Kingdom. The

manner of agricultural utilisation of rough pastures and the production therefrom, including the extent to which agricultural and pastoral farming contribute to rural prosperity in comparison with the possibilities of sylviculture if prosecuted in a judicious and proper manner. A comparative statement of the situation as disclosed by recent investigations and available statistics. A suggestion that the utilisation of land should be regulated by the requirement of the nation for the produce of grazing lands and the produce of afforestable land. That the highest production from any area and the source of the maximum employment are material factors in determining the future policy in respect to both industries. Further that there is scope for an expansion of afforestation without serious encroachment upon existing utilisation.

SECTION L.—EDUCATIONAL SCIENCE.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 688.)

Thursday, September 6.

The Marking and Standardisation of Composition. Papers—

(*a*) Dr. G. Perrie Williams. (Dr. Perrie Williams' paper was read, in her absence, by Mr. W. W. Vaughan.)

(*b*) Mr. D. B. Mair.

A satisfactory examination in English Composition as in other subjects must do two things. It must arrange the candidates in order of merit and it must assign to each candidate a mark that truly represents his value. For the first of these requisites we must rely on the judgment of the examiner; for the second it is possible to provide machinery to assist his judgment.

The order of merit depends upon the object with which the examination is held. The specification of the object determines the relative importance of the virtues that can be shown in an essay and consequently the appropriate order of merit of the candidates.

The valuing of the essays may be done by the analytical method or by the impression method. On the analytical method the candidate is marked separately for the various virtues and his value obtained by the addition of the separate marks. On the impression method a single judgment is made as to the value of the candidate for the purpose in question. The impression method gives more accurate results.

The second requisite of a satisfactory examination is that the mark assiged to each candidate shall truly represent his value. For this we bring to the examiner's aid the principle of the constancy of the average candidate. When there are no special circumstances and the candidates are in sufficient number, we are justified in assuming that the distribution of the candidates among the possible marks should be normal. By means of the Pearson formula for normal distributions and Bryan's device for converting any distribution into a normal distribution, we carry out on the examiner's marks (in any case in which adjustment is necessary) an adjustment that will result in a normal distribution of the candidates. This done, the adjusted mark of each candidate represents his true value more accurately than is possible by the unaided judgment of the examiner.

Discussion (Mr. J. L. Holland, Miss Young, Dr. J. White).

Joint Discussion with Section G (*q.v.*) on *School, University, and Practical Training in the Education of the Engineer.* (Sir William Ellis, G.B.E.; Col. Ivor Curtis, C.B.E.; Sir Henry Fowler, K.B.E.; Mr. W. W. Vaughan.)

AFTERNOON.

Stow Commemoration Meeting and Garden Party, Glasgow Provincial Training College, Jordanhill.

Opening statement—Rev. ALEXANDER ANDREW.

Address—Dr. CYRIL NORWOOD. Plantation of Commemorative Trees.

Friday, September 7.

Presidential Address by Dr. CYRIL NORWOOD on *Education: The Next Steps.* (See p. 200.)

The Methods and Results of Educational Research. Papers—

(*a*) Dr. J. DREVER.—*Definition and Statement.*

Research in science is not mere 'fooling around' with novelties in the hope that something will turn up. It must always be guided by a clear and definite question. Moreover, the methods employed must be such that an answer to the question is possible. In particular it is important that conditions should be known and controlled so that only those which are relevant to the question are varied, and the variation is under control. These are general principles of all scientific research.

Research in education differs in the same way as research in any other applied science from research in the pure sciences. Its problems are definitely practical problems. In every case they have their origin, directly or indirectly, in the practice of education. Their solution also must be capable of direct translation into terms of educational practice. Like some of the other applied sciences educational science has to deal with problems which are really in the fields of various pure sciences, such as psychology and physiology. But it differs from all other applied sciences in that its aims are determined in the last resort by a philosophy of life, which is scarcely amenable to research in the ordinarily understood scientific sense.

The problems of educational research may be classified in various ways, as:

1. Problems of (*a*) organisation, (*b*) classification, (*c*) instruction,

or

2. Problems of (*a*) analysis, (*b*) method, (*c*) testing and statistics,

or

3. Problems of (*a*) character, (*b*) knowledge, (*c*) skill.

(*b*) Dr. J. H. STEEL.—*The Routine Work of the Classroom.*

(*c*) Dr. R. R. RUSK.—*The Technique and Organisation of Research.*

What research is, and what term 'technique of research' connotes. Common factors in research: specific factors in educational research. Relation of educational research to psychological research. Aspects of educational research—history, administration, finance, curriculum, learning process, discipline.

Methods of educational research. 'Mass' versus 'individual' methods. Statistical methods.

Organisation of research. Necessity for Bureau, or Institute, of Educational Research. Functions of Institute—assist and inspire individual workers, organise co-operative research, collect data, record failures, collect, collate and disseminate reports of research work in forms suitable for application in schoolroom, act as clearing house for new instructional methods, devices, apparatus, equipment, &c.

Function of Pedagogical Clinic and its relation to Institute of Educational Research.

What teacher may expect from educational research, and what educational research may require of the teacher.

Discussion (Mr. D. KENNEDY FRASER, Dr. R. H. THOULESS).

AFTERNOON.

Demonstration of Music in the Schools. Mr. HUGH S. ROBERTON—Address on *School Music.*

Musical Display arranged by Mr. HUGH HUNTER :—
(*a*) Infants—Oatland Street School.
(*b*) Special School—Percy Street.
(*c*) Boys' Choir—Strathburg School.
(*d*) The Junior Orpheus Choir.

Monday, September 10.

The Work of Post-Primary Education in Scotland. Papers—

(*a*) Mr. JOHN CLARK, C.B.E.—*A National Survey.*

(*b*) Mr. G. A. BURNETT.—*The Training College Aspect.*

(*c*) Dr. P. PINKERTON.—*The Secondary School Aspect.*

(*d*) Dr. A. P. LAURIE.—*The Technical School Aspect.*

(*e*) Prof. W. W. MCCLELLAND.—*The University Aspect.*

Discussion (Miss MCLARTY ; Mr. J. C. SCOTT ; Mr. M. MACKINNON, and Mr. BURDON).

Report of Committee on *Science in the School Certificate Examinations.* (Sir RICHARD GREGORY.)

Discussion (Prof. TATTERSALL, Mr. W. H. BARKER, Mr. W. M. HELLER).

Committee on *Recent Views on Formal Training.* (Statement by Dr. C. W. KIMMINS.)

AFTERNOON.

Visits to Schools (Burnside Special School, Glenboig Holiday School, Percy Street Special School, Hillfoot Holiday School, &c.).

Tuesday, September 11.

Aims of, and Developments in Broadcasting. Papers—

(*a*) Mr. J. C. STOBART.—*Wireless in the Service of Education.*

Broadcasting, a novelty five years ago, regarded as a toy ; to-day an influence of the first magnitude. From the beginning the B.B.C. has been conducted as a public service. The responsibilities appreciated and a determination manifest to exploit its potentialities to the maximum extent. Entertainment primary function, but the educational and general cultural possibilities recognised and developed. The idealism of this attitude fully vindicated by an increasing appreciation of educational talks, general and specific, good music, religious features, literature, &c. Entertainment

and education should overlap, certainly need not be considered definitely distinct from each other. General educational implications in classical music, grand opera, literary plays and readings, news bulletins (from which mere sensationalism is excluded), topical talks selected so as to give an understanding of current problems in politics, economics, &c., and to keep listeners in touch with progress and achievement in every line of human activity. Specific educational activities in two classes—Adult and Schools. In both cases talks, almost invariably given in series of six to twelve, are supplemented by 'follow-up' work of various kinds, 'Aids to Study' pamphlets, &c., containing bibliographies, notes and illustrations, to be used in conjunction with the talks. Co-operation essential at the listening end in both cases. As to adult education, the B.B.C. and the British Institute of Adult Education formed a joint committee under the chairmanship of Sir Henry Hadow, and the committee's report, entitled 'New Ventures in Broadcasting,' published in the spring, created widespread interest. Explains how broadcasting widens the field from which students are drawn, and puts listeners in touch with leaders of thought and the chief experts in many subjects. Contact between mind and mind a vital part of educational process and discussion groups should be encouraged. Creation of a central council suggested, with certain powers and responsibilities in connection with adult education work. In the meantime a small interim committee under Lord Justice Sankey is formulating a plan for the establishment and authority of such a council. The Hadow Committee recommended that part of the revenue from licences now retained by the Postmaster-General over and above the costs of collection and administration should be handed over to the Council.

The conclusions of an exhaustive experiment conducted by the Kent Education Authority (with a grant from the Carnegie United Kingdom Trustees) were published in a report this summer. The regular broadcasting of a daily lesson in term time has proceeded for four years, and over 5,000 schools avail themselves of this opportunity. Similar machinery to that for adult education is proposed.

(*b*) Mr. Salter Davis.—*An Experiment in Educational Broadcasting.*

Discussion (Sir William Bragg, K.B.E., F.R.S.; Sir Oliver Lodge, F.R.S.; Mr. Watson Davis).

Demonstrations of wireless reception suitable for school classrooms; model studio, &c.

Educational Clinics and Psychological Tests. Papers—

(*a*) Dr. W. Boyd.—*The work of Educational Clinics.*

(*b*) Dr. R. H. Crowley.—*The Need for and Organisation of Child Guidance Clinics, with special reference to American Experience.*

During the last few decades there has been a general movement to pass from the child in the mass to the child in groups. Blind, deaf, mentally defective, crippled and, more recently, delicate, dull, backward, partially blind, partially deaf children, have been grouped for purposes of special study and appropriate treatment. Attention is now becoming focussed on the 'mal-adjusted,' the 'difficult,' the 'delinquent,' and the 'anti-social' child, and on the signs and symptoms of temperamental abnormalities in their earliest stages and the relation of these to more serious manifestations in later life. Reference is made to the arrangements at present existing in this country for dealing with children presenting these character traits, and some account is given of the working of a typical child guidance clinic, based upon visits paid by the writer at the invitation of the Commonwealth Fund of New York to various child guidance clinics in the United States. The different aspects of the work are described under the headings of Service, Teaching, Educational Propaganda, and Research. The organisation of a child guidance clinic is described, with special reference to its associations with the educational system of the area, the Infant Welfare and School Medical services, the various voluntary Child Welfare organisations and institutes, the Children's Court and Probation Officer service, the general medical practitioner,

the hospital, the university. Some account is given of the activities of the Child Guidance Council recently established in London, and of the proposal to set up in London a child guidance clinic as a demonstration clinic financed for a period of three years by the Commonwealth Fund of New York.

(c) Miss M. Drummond.—*The Scope of the Child Guidance Clinic.*

The Child Guidance Clinic may be regarded as having both length and breadth. Its length is to be measured in terms of the ages of those who attend it; its breadth in terms of their complaints, symptoms, abilities, and disabilities.

The aim of the clinic is to readjust children who in one way or another are out of harmony with their environment. Such maladjustments take many forms—stealing, lying, sexual aberrancies, educational disabilities, bad temper, are a few of the most important. Malnutrition may also be regarded as lack of adjustment to environment. This is the most common form of protest in infancy, but is best dealt with by the medical man who alters the environment. The work of the Child Guidance Clinic begins when the mental element becomes more accessible, that is, round about the age of two. It may continue until the age of fourteen or even sixteen, but it is clear that the more the need for readjustment is realised in the early years, the rarer will become the older cases.

The methods of the clinic are psychological methods. The Director of the Clinic must, therefore, be a psychologist. It may be an advantage if he has medical qualifications as well; in any case he must obviously work in close association with a medical man.

Special Demonstration of Educational Broadcasting.

SECTION M.—AGRICULTURE.

(For reference to the publication elsewhere of communications entered in the following list of transactions, see p. 688.)

Thursday, September 6.

Presidential Address by Dr. J. S. Gordon, C.B.E., on *The Live Stock Industry and its Development.* (See p. 213.)

Discussion (Sir Robert Greig; Prof. J. A. S. Watson; Mr. A. W. Montgomerie; Mr. John Speir; Prof. R. G. White).

Afternoon.

Mr. A. Crichton.—*Supplementary Feeding on Pastures for Sheep and Cattle.*

A survey of the pastures on rough grazings during the last two or three years has shown that on pastures which have never been cultivated or treated with fertilisers the chemical composition varies in different districts, and in many cases the amounts of protein and some of the essential minerals present are, on the basis of the energy or starch value, very low. It is suggested that these substances which are deficient are limiting factors for the utilisation of the pastures by the animal, and that in some cases where the deficiencies are extreme they are the direct cause of malnutrition.

Acting on this hypothesis feeding experiments have been carried out with cattle and sheep in Kenya Colony and in Scotland.

The data from these feeding tests show that in some cases the feeding of the appropriate mineral salts on deficient pastures has resulted in increased growth in young animals, and greater wool or milk production. Some of the figures suggest that the feeding has had an influence in reducing the amount of disease.

Mr. Donald MacKelvie.—*Breeding of Potatoes.*

Mr. M. M. Monie.—*The Soils of West Stirlingshire.*

Friday, September 7.

Joint Discussion with Section I (*q.v.*) on *Lactation and Nutritiona Factors allied thereto.*

Rt. Hon. Lord Bledisloe, K.B.E.—*Grassland Improvement.*

Need for better grassland farming with temporary decay of arable husbandry.
Pasture a crop.
Applicability of Dr. Warmbole's methods to British conditions.
Protein in young grasses comparable with that in clover.

Outline of System.

(1) Cultural treatment; (2) Repeated fertiliser dressings; (3) Close rotational grazing period lengthened. Stock carrying capacity increased. Not 'Three acres and a cow,' but 'Three cows and an acre.'

Leafy indigenous strains of herbage respond most to nitrogenous fertilisers. Hardening effect of potash.

Mineral content of pasture adequate if intensively treated. Effect on milk yields.

Size of fields for rotational grazing unimportant. Importance of mowing machine.

Intensive system specially applicable to Small Holdings. Output of British Small Holdings far too small.

Economic justification of Intensive System.

Afternoon.

Dr. D. N. McArthur.—*Mineral Metabolism of Swedes.*

The primary object of the investigation was the study of the effect of a phosphatic fertiliser upon the metabolism of the swede. The phosphate used was a silicophosphate whose molecular constitution was determined by the co-ordination of metallographic, petrographic and chemical examinations.

The variety of swede used was 'Scotia'—chosen because it showed uniformity in great measure. The plants were grown on two plots and samples were taken regularly throughout the summer and winter months. At each sampling, fifty plants were taken from each plot and from these representative portions of bulb and leaf were drawn. Between June and September the sampling was conducted at intervals of fourteen days and thereafter at intervals of thirty days. The 'control plot' received no manurial treatment, while the 'manured plot' received an application of the silicophosphate.

The percentage of dry matter was determined in each sample and subsequently the weights of dry matter in the fifty plants (bulbs and leaves calculated separately) were calculated. The dry matter obtained at each sampling was analysed for calcium, phosphorus, nitrogen and silica. From the percentages obtained the molecular ratios were calculated, taking lime as unity in all cases.

During the first fifty days of growth the absorption of calcium, phosphorus and nitrogen was slow, but rapidly increased during the following ten days. The rates of absorption of calcium and nitrogen were similar but phosphorus was absorbed at a slower rate during the first sixty days. Each of the mineral elements in the leaves, except silicon, was translocated to the bulb at the end of the first year's growth. The calcium was returned earlier than the phosphorus but was also translocated back to the leaves at an earlier date in the second year's growth.

The metabolism of calcium in the leaf appears to be a function of the nitrogen metabolism or vice versa.

The increase in weight of the bulb during November and December is largely due to an increased absorption of water, and evidence was obtained to support the

'practical' contention that the 'Scotia' swedes mature, relative to other varieties, at a later date.

The effect of the silicophosphate was to produce bulbs having more dry matter and 'carbohydrate.' The phosphate content of the manured plants was greater but the distribution between leaves and bulb was similar to that in the control plants. After production of maximum amount of dry matter in the leaf, the 'calcium-phosphorus' molecular composition of the leaves was nearly the same in both series, the manured bulbs then containing more phosphorus. The silicon absorbed was not translocated to the leaf so early as in the case of the 'control' plants. The manured bulb absorbed more silica but it was retained in the bulb, while, in absence of sufficient phosphorus, the control plant utilised more silica in the leaf. A comparison of the molecular composition of the control and manured bulbs shows that mineral composition of the dry matter was modified by the manurial treatment.

The 'calcium-nitrogen' molecular ratio in the dry matter of the leaves was not influenced by the application of the silicophosphate.

The 'calcium-phosphorus-nitrogen' molecular composition of the manured bulbs was constant during November, December and January.

The mineral molecular composition of the manured bulb at the first sampling was similar to that of the silicophosphate applied.

Prof. R. H. Leitch.—*Cheese Defects, Biological and Biochemical Factors.*

Dr. A. C. McCandlish.—*The Place of Succulent Feeds in the Dairy Ration.*

During recent years there has been much discussion on the value of succulent feeds for milk production. Roots have generally been looked on as one of the mainstays of the dairy farm in the south-west of Scotland, but some now say that milk can be produced more cheaply without than with them. Then many claims have been put forward for the silo as a labour-saving device, while dried beet pulp has also received considerable attention. The results from a number of trials on these problems at the West of Scotland Agricultural College are now available.

Silage and Swedes.

In three trials silage was compared with swedes, and it was found that on the average $11\frac{3}{4}$ cwt. of silage was equivalent to one ton of swedes. If an allowance of 10 per cent. be made for losses in the silo, then 12 tons $11\frac{3}{4}$ cwt. of silage must be produced per acre to get the same feeding returns as from a 20-ton crop of swedes, or 19 tons $7\frac{3}{4}$ cwt. silage to be equal to 30 tons of swedes. The silage must be fed out of the silo at a cost not exceeding 26*s*. per ton to be as economical as swedes costing 15*s*. per ton.

Dried Beet Pulp.

It is sometimes said that dried beet pulp has a depressing influence on the composition of milk, especially in so far as the solids not fat are concerned, but experimental work shows that this is not the case. In a trial where the dried pulp was compared with swedes it was found that $3\frac{3}{4}$ cwt. of pulp was equivalent to one ton of swedes, and with swedes at 15*s*. per ton the dried beet pulp was worth £4 per ton.

Roots or No Roots.

In one trial which has been completed a ration of 40 lb. swedes and 12 lb. hay was compared with 20 lb. hay, suitable grain allowances being given in each case. An increase of 4 per cent. in milk and fat production was obtained when the roots were fed and the cost of milk production was lowered by $\frac{1}{2}d$. per gallon. A further trial, which is being carried through at least two lactations, is in agreement with this so far.

The Root Allowance.

Allowances of 40 and 60 lb. of roots have been compared, and it was found that the increase in the root allowance, with a decrease in the allowance of concentrates, brought about no change in yield, but each extra 10 lb. of roots fed was equivalent to 1 lb. of concentrates and had a value of £1 per ton.

Summary.

Swedes, silage and dried beet pulp give good results for milk production, and the choice of succulent feed will depend on cost. Use the one which can be obtained at the lowest relative cost. Milk can be produced without succulent feeds, but where they can be produced they are of value in the dairy ration.

Mr. D. G. O'Brien.—*The Endotrophic Mycorrhiza of the Strawberry and its Significance.*

The paper contains the results of a mycological investigation, undertaken in the years 1926 and 1927, into a serious disease of strawberries in the Clyde Valley of Scotland, known locally as 'The Lanarkshire Strawberry Disease.' The investigation was first confined to the disease as it occurs in Lanarkshire, but later was extended to include strawberry-growing districts throughout Great Britain, as evidence was forthcoming to show that the symptoms throughout the country had various points in common.

In view of the complex nature and widespread occurrence of the trouble, it should be understood that much research work still remains to be done before the problem is finally solved; meantime, on the evidence presented in this paper, the authors have come to the following conclusions as to the cause and nature of the disease :—

1. The disease of strawberries, best defined as 'root weakness,' is a general one.
2. Diseased plants are characterised by a paucity of absorbing rootlets. The other symptoms of the disease are but signs of starvation consequent upon this.
3. The only constant organism found in the living roots of unhealthy plants is an endotrophic mycorrhizal fungus of the type bearing arbuscules and vésicules.
4. This organism invades chiefly the fine absorbing roots of the strawberry plant.
5. At or about flowering time of the strawberry plant, fine fibrous roots are produced in great amount and, coincident with this, the maximum infestation occurs. The disease is most destructive at this critical stage.
6. Starch and other materials are removed from the root tissues by the action of the arbuscules, and there is no evidence of any return of starch to cells when once depleted of their contents. The vitality of the roots is therefore lowered.
7. The arbuscules are never completely digested by the host cells, so that the fungus benefits at the expense of the plant.
8. At the points where strong infestation occurs the finer rootlets are ruptured and drop off into the soil. To this we ascribe the poverty of absorbing roots noted on diseased strawberry plants.
9. We regard this endotrophic mycorrhizal fungus as a parasite, and believe it to be the fundamental cause of the disease.
10. The disease tends to be slow-acting and chronic in its nature, but the fungus is capable of bringing about death of the plant if infection is severe.
11. The disease assumes really serious proportions when aggravated by conditions inimical to the growth of the strawberry plant. But, according as the mycorrhizal attack is severe or slight, and as conditions are unfavourable or favourable for plant growth, so is the ultimate damage greater or less.
12. The so-called 'Lanarkshire Strawberry Disease' represents this trouble in its most serious form.
13. The endotrophic mycorrhizal fungus paves the way for the entry of secondary fungi and bacteria which, under certain conditions, may invade the weakened root tissues and intensify the disease.
14. The root fragments, which are broken off from diseased plants, serve to infect the surrounding soil.
15. Young runners from affected plants are free from disease until they strike root in the soil, when their roots become infected.
16. The disease is transmitted by infected runners.
17. Some evidence is produced to show that the fungus is not specific to the strawberry, but may invade other plants such as grasses and clovers. Infection of the strawberry crop may be traced to such sources.
18. Control measures are outlined.

Saturday, September 8.

Excursion (motor charabanc) to Ayr *via* Johnston, Dalry, Barassie, Loans, Troon, Monkton, to view soil profiles, small holdings, etc. Return *via* Auchincruive, Holmes Farm, Rowallan Castle (tea), Lugton.

Monday, September 10.

Dr. J. F. Tocher.—*A Milk Survey: Recent Results of a Study of the Variations in the Composition of Milk.*

For the past fifteen years a systematic study has been made of the composition of cows' milk from many thousands of cows. Variations in composition have been determined for different breeds of dairy cows, different ages of cows, and different durations of lactation period, seasons and areas. The proportions of butter fat and solids not fat vary widely during a lactation period and decrease steadily with age of cow. A positive correlation exists between butter-fat and solids-not-fat percentages in samples of milk from individual cows taken on the same day. Thus a good butter-fat producer is, on an average, a good solids-not-fat producer. On the other hand a negative correlation has been found to exist between butter-fat and solids-not-fat percentages in the daily samples of bulked milk from the same herd. This is due to the tendency of a herd to give day after day a constant proportion of total solids (*i.e.* butter fat plus solids not fat). Daily samples of bulked milk from a fairly large herd show greater variations in constituents than have hitherto been supposed. As expected, the smaller the herd the greater were the daily variations in the constituents. Friesians show the highest *proportion* of sugar and the highest yield of butter fat for a lactation period, both owing to their higher yields. Ayrshires show the highest *proportions* of protein and butter fat. The system of milk recording which has been in existence in Scotland for twenty-five years has had a very material effect in improving the quality of milk among the herds of members of the Scottish Milk Records Association. Yield of milk has been found to be largely a function of age as well as a function of breed, duration of lactation period, and other factors. It is to be noted that the data obtained from the Scottish Milk Records Association are data of cows which are more or less selected. It might thus be held that yield was a function of age because of this selection. It has, however, been established that yield is a function of age both for selected and unselected groups of cows. A selected group differs markedly from an unselected group in showing increased yield with age from seven years onwards. The effect of the elimination of poor milkers at the younger ages is clearly evident in the increased yield among the older cows in the selected herds when compared with the corresponding yields of older cows in unselected herds. An important fact must however be specially noted, namely, that the variabilities of yield for various ages increase steadily with age. Selection is, therefore, not stringent. The least variable over a period of years in average weekly yield of good cows should be selected for milk production for succeeding lactation periods.

The following figures are abstracted from a table in a memoir about to be published showing the average yield of butter fat in pounds for a given age of cow and a given length of lactation period. This table should prove of practical value to milk producers.

Weeks in Milk	Age of Cow. 2	3	4	5	6	7	8	9	10	11	
26	132	147	160	171	180	186	190	192	191	189	pounds
38	210	227	241	253	263	271	276	279	280	279	,,
50	276	294	309	323	334	343	349	354	356	355	,,

Mr. A. E. Magee.—*Milk Selling Agency.*

Prof. R. A. Berry and Mr. A. Macneilage.—*Utilisation of Surplus Milk and Milk Residues.*

Afternoon.

Mr. H. R. Davidson.—*Reproductive Disturbances caused by Feeding Protein-deficient and Calcium-deficient Rations to Breeding Pigs.*

The number of fœtuses which undergo atrophy in the uterus of the sow is known to be large, and according to the investigations of Marshall and Hammond this degeneration is due neither to bacterial infection nor to overcrowding. A genetic lethal factor has been suggested, but as atrophy takes place at all stages of development

it seemed probable that nutritional variation is also responsible. As protein and calcium are known to be essential for young growing animals, it was decided to investigate the effect of deficiencies of these constituents on breeding sows. Three pens of female pigs were placed under experiment on rations which were, respectively, complete, deficient in digestible crude protein, and deficient in calcium. Two-thirds of these pigs were slaughtered at the end of the third month of pregnancy (gestation lasts four months) and the remainder allowed to farrow. The offspring were reared on the same ration as the dams, the male pigs were removed from experiment at weaning, and the remaining female pigs dealt with as the first generation. The experiment lasted for 3½ years, during which time the following observations were made.

The pigs on the complete ration formed an effective control. They grew more rapidly, bred more regularly, and remained in better health and freer from accidents than the other two pens. The progress of the pigs on the protein-deficient diet was very greatly retarded, partly owing to a very slow rate of growth in the earlier stages and partly owing to interference with breeding. Among the pigs on the calcium-deficient ration the most obvious features were, first, the large proportion of accidents occurring, and also the increasing amount of ill-health and deaths amongst the sucking and newly weaned pigs.

A steady rise in numbers of atrophic fœtuses from slaughtered sows in the complete pens as compared with the small numbers in the other pens showed that some factor other than a deficiency of protein or calcium was partly responsible. A comparison of the figures at birth on the other hand showed a very definite increase of dead pigs in each successive generation on the calcium-deficient diet. The average live weight at 16 weeks of the complete pigs fell from 56 lb. in the first generation to 34 lb. in the third, whereas with the calcium-deficient pigs the first generation weight was 49 lb., and the third litter of the second generation only 13 lb.

As the experiment progressed, the return of œstrus after weaning tended to be delayed on the protein-deficient ration, whereas on the calcium-deficient diet the most noticeable progressive observation was the lack of udder development and the apparent starvation of the sucking pigs. Deaths from broken bones and from peritonitis following injury at service were observed only in the calcium-deficient pigs. It is suggested that the investigation points to the following conclusions :

(1) Fœtal atrophy is not directly caused by a deficiency of protein or calcium in the food of the sow.

(2) A serious deficiency in the body supply of protein or calcium in the pig requires one or two generations to become established.

(3) Calcium deficiency leads to an increasing reduction of the milk supply in sows, coupled with an increasing number of pigs born dead. The combination of these two results leads to extinction after two or three generations.

(4) Protein deficiency when vitamins and mineral salts are adequate produces very marked reduction in rate of growth and probably in rate of breeding, but does not lead to lack of milk supply, increase in disease, or to deaths at birth.

Mr. J. A. Fraser Roberts.—*Wool Research and the Farmer.*

Many aspects of wool production present a favourable field for scientific research. Although in this country wool is a secondary product of agriculture, it is nevertheless one in whose sale the farmer has a direct interest. Equally as it is a by-product, it is to be expected that the gap between the producer and the consumer would be wider than usual. This tendency is made more marked owing to the rapid changes of fashion which make the demand fluctuating and variable. The result is that there is probably no field in agricultural production where the interests of the consumer are less studied. There is an exceptionally favourable field for scientific research designed to standardise and to classify and so make possible an attempt to bridge that gap.

To the breeder the fleece is more than a saleable commodity ; it is an efficient covering, or otherwise, intimately connected with the well-being of the animal. Also, as wool in this country is not the main aim of sheep-breeding, any indirect connexion with other important qualities is of importance.

This paper is an attempt to show how research on wool can be of assistance to the farmer in these and other directions.

Dr. J. E. Nichols.—*Some Aspects of the Ecology of British Sheep.*

It can be demonstrated that, in spite of the disturbances caused by domestic husbandry, the sheep is limited in its distribution by a series of environmental conditions; domestication has resulted in the development of different types within the species and selection has caused the establishment of more or less well-defined 'breeds.'

The British Isles lie completely within the range of conditions for successful sheep husbandry, but within the Isles great local differences in environment exist, and to meet local conditions of environment and economic demand many different types or breeds have been selected. Thus within the general sheep population the different breeds have different distributions and perform different functions, and it would seem that each particular type is associated with different environmental optima. The definition of the conditions which limit the distribution of each type is being attempted.

The position is obscured by the widespread practice of cross-breeding for commercial purposes, but by considering only the aggregations of pure-bred flocks the major considerations can be examined and the indication of the most beneficial environment for a particular type or breed, or the most suitable type for a particular environment, can be accomplished.

Two main avenues of approach to the problem are presented: the first is by the study of the histories of development and spread of the breeds, in many phases of which the method of trial and error was mainly used; the second is by analysis of the environment of the breeds to-day.

The chief distinction between types which can be made is that between mountain and lowland sheep; associated with the differences in altitude are differences in temperature and rainfall conditions. The primary differences cannot easily be established, but broad distinctions can be made irrespective of whether the effects of, *e.g.* climatic conditions, are direct or are indirectly manifested through their effects on the nutritional supply or the methods of husbandry employed.

An attempt has been made to dissociate the effects of one series of environmental conditions from the other in the case of altitude, temperature and rainfall, and the results of the analysis indicate that it is possible to define the optimum conditions for successful husbandry of particular breeds, and to define the breeds suitable for certain sets of conditions. The critical periods, such as service and lambing periods, are found to fall within closely related limits of environment.

Mr. A. D. Buchanan Smith.—*Inbreeding in Jersey Cattle.* (See p. 649.)

Tuesday, September 11.

Joint Discussion with Section F (*q.v.*) on *The Incidence of Taxation in Agriculture.*

Mr. D. A. E. Harkness.—*The Economics of Small Farms.*

One of the most important problems in connection with the agricultural industry to-day is the question of the best economic and social unit for farm production. In most countries of the world the preponderance of small farms is increasing, and in Great Britain there is a widespread demand that the land should be made to afford a livelihood for a greater number of the population. Unfortunately, comparatively little information is available regarding the economic position of small farms.

A comparison of the results of the census of production inquiries which were made in 1925 in England and Wales and in Northern Ireland shows that in the latter country—which is a country of small farms—the value of the gross output per acre is less than in England and Wales, where the bulk of the agricultural area is divided into relatively large-sized farms. A greater proportion of the agricultural output of Northern Ireland is, however, comprised of live stock and live stock products than is the case in England and Wales. Owing to the small proportion of the crops sold off farms in Northern Ireland the value of the output per acre is depressed.

After deducting rent, wages of hired labourers and rates on agricultural land from the value of the net output of the agricultural industry in Northern Ireland a surplus averaging slightly over £3 per acre was available in 1925 to remunerate the farmer

in respect of his labour and capital. If all farmers and male members of their families received the current rate of agricultural wages, the balance would be insufficient to pay normal interest on the capital invested in the agricultural industry. Much of the family labour on farms is, however, of a part-time character, so that the allowance of current wage rates to all male members of the family returned as working on the farm at June 1 probably represents an excessive payment for the work performed.

While the output of foodstuffs per acre on the smaller farms of Northern Ireland appears to be appreciably greater than on the larger holdings, the employment of labourers, horses and implements per unit of land is also greater on the smaller farms.

The tabulation of the statistical returns for a large area in one of the best farming districts of Northern Ireland shows that on one-horse farms the area ploughed per horse is higher than on farms with a greater number of horses, but the percentage of land ploughed on one-horse farms is appreciably lower than on farms with two or more horses.

Afternoon.

Joint Discussion with Section K (Department of Forestry, *q.v.*) on *The Economic Balance of Agriculture and Forestry.*

DISCUSSION ON THE TEACHING OF GEOGRAPHY IN SCOTTISH SCHOOLS.

MONDAY, SEPTEMBER 10TH.

THE PRESIDENT of the Geographical Section (Prof. J. L. Myres) introduced the subject of the discussion by reading extracts from the Report of the Scottish members of the Association's Committee on Geographical Teaching, presented to the Geographical Section at Leeds in September 1927, and communicated through the Council of the Association to the Scottish Education Department. He also read the reply of the Department, as follows :—

SCOTTISH EDUCATION DEPARTMENT,
14 Queen Street, *27th August*, 1928.
Edinburgh.

LEAVING CERTIFICATES—HISTORY AND GEOGRAPHY.
28/E. 5260.

SIR,

Adverting to your letter of 5th June last, I am directed to state that the Report of the Committee of the British Association on the teaching of Geography in the Scottish schools has received most careful consideration.

The Department fully realise the importance of the issues raised in the Report, and they desire to assure the Committee that they do not in any way underrate the value of the study of Geography. At the same time they have to take account of the claims of the various subjects that compete for a place in a well-balanced secondary course. The structure of the secondary school curriculum and the conditions governing presentation for the Leaving Certificate examinations are under constant and vigilant observation, and the Department are satisfied that there is no ground for the suggestion that the study of Geography is relegated to a position of undeserved inferiority.

In connection with the Report the Department would direct the attention of the Committee to several particular points :—

1. In their reference to the abolition of the Intermediate Certificate the Committee have apparently failed to take account of the Day School Certificate (Higher), which replaces the Intermediate Certificate and requires an equivalent standard of attainment. All the three-year Advanced Division Courses leading to the award of the new Certificate must include Geography, and the number of candidates in the last session for which statistics are available was about 5,200. If to this number be added the number of candidates who are presented in Geography at the Leaving Certificate Examination (at present about 200) the total compares on a population basis not unfavourably with the 35,000 candidates in England and Wales referred to at the end of the Committee's Report.

2. It is not the case that Geography has been reduced to the equivalent of a half subject as compared with Art, Music or Domestic Science. Art, Music and Domestic Science do not rank as Higher Subjects for the minimum Leaving Certificate group, whereas Geography in combination with another Science does. Under the old regulations Geography on the Higher standard could be professed only as an additional subject, but any approved combination of Geography and Science now ranks as a Group II (Circular 62) subject, and may be professed either on the Lower or on the Higher grade.

3. The Committee are of opinion that the Lower standard may be reached after three years' study. This opinion is hardly in accord with the general experience. Candidates professing the Lower standard, equally with those presented on the Higher, have usually followed a five or a six years' course.

4. The Committee state that it is certain that the number of schools and candidates offering Higher Geography has greatly declined in the last two years, *i.e.*, in 1926 and 1927. This is true only of presentation in Geography as a separate subject and the decrease is natural, as since 1924 Higher Geography could be offered only by the rapidly decreasing number of pupils who had reached the stage of the Intermediate Certificate in 1924 or earlier. The Committee are aware that the last candidates under the old system were examined in 1927. On the other hand, there is a steady increase, both at the Lower and at the Higher stage, in the number of schools and candidates taking Geography in combination with another branch of Science, and the

total presentations in Geography are now actually more numerous than they were under the old conditions.

Some further particulars under this head may be of interest to the Committee.

(1) The number of schools conducted under the Secondary Schools (Scotland) Regulations which have courses including five and four years of Geography study beyond the Primary stage is 36 and 7 respectively. In addition there are 35 schools which prepare candidates for the Leaving Certificate Examination in Geography in combination with another Science at the end of a course extending as a rule to five or six years. The remaining 174 schools under the Secondary Schools (Scotland) Regulations include in their curriculum a course of three years study of Geography. Two hundred and twenty of the schools under the Secondary Schools (Scotland) Regulations present candidates for the Day School Certificate (Higher); in addition there are 169 other schools which present for that Certificate. The number of schools which present candidates in English, including Geography as an obligatory subject, is already 50 in excess of the number examined in 1924 for the Intermediate Certificate.

(2) The total average enrolment of post-primary pupils in schools conducted under the Secondary Schools (Scotland) Regulations in 1926–27 was 80,506. Of these 66,399 (or 82·5 per cent.) were enrolled in the first three years of the secondary course, in which the study of Geography is universal. If the average enrolment of classes in which Geography is studied in the fourth, fifth and sixth years is added, the result would be an appreciable raising of the percentage.

(3) The number of pupils presented in Geography and Science combinations on the Higher grade in 1927 was 62; in 1928 it was 75. At the lower stage the number of presentations in Geography increased from 76 in 1927 to 127 in 1928. These figures indicate a growing appreciation of the new arrangements.

5. It should be added that the Department have not confined themselves to a statistical watchfulness in this matter. H.M. Inspectors are required to report periodically not only upon the instruction in individual schools, but also upon the general position of the various subjects throughout the country. In this respect Geography has had its full share of attention. The reports indicate that the instruction in Geography is sound and thorough; that the system of presentation in the Geography-Science combination has made a very promising beginning; that at the lower stage of presentation in Geography-Science the work is good and well beyond the old intermediate standard; and that the subject of Geography has received a marked stimulus in the Secondary Schools.

6. The Committee state that approval of courses 'is presumably in the hands of Inspectors whose University training has not included Geography, and whose sympathies consequently tend to favour other sciences.' The presumption is groundless. The approval of courses lies with the Department; and, while the conditions governing the framing of courses and the subjects of presentation are now very elastic, expert and sympathetic consideration is given to each subject included in every scheme submitted by the schools as a genuine contribution towards a sound course of instruction.

7. The Department note the Committee's reference to the regulations of the Scottish Universities Entrance Board of February 1927, but they would point out that whereas under these regulations a pass in Science could not be counted as a Higher pass unless it included Physics, a pass in a combination of Geography and Natural Science will, under the more recent regulations, count as a Higher pass.

In conclusion the Department, while thanking the General Committee and the Council for their communication, the contents of which will certainly not be lost sight of, would suggest that some further time should be allowed to elapse before a definite judgment is passed on the effect of the recent changes so far as the position of Geography is concerned. It is probably in the meanwhile inevitable that the treatment of this, as of other individual subjects, may appear to be inadequate to those who are specially interested in them, but who may not have a full opportunity of appreciating the strength of competing claims or the magnitude of the task which pupils have to face in the whole range of their school work.

I have the honour to be, Sir,
Your obedient Servant,
(sgd.) W. W. McKechnie.

The General Secretary,
British Association for the
Advancement of Science.

Mr. JOHN McFARLANE, Reader in Geography, University of Aberdeen.—'I have been asked to open the discussion on this important subject by drawing your attention to the Report presented by the Scottish members of the Committee appointed by the Council of the Association to consider the teaching of Geography in Scottish schools. This report was sent to the Scottish Education Department in the latter part of last year, and less than a fortnight ago the General Secretaries received a reply from the Department traversing some of the statements made in the Report. Owing to the shortness of time at their disposal the Scottish members of the committee had not been able to obtain all the information they required to deal with this reply, but it is hoped that a brief examination of the two documents, the Report and the reply made to it, will suffice to indicate the present unsatisfactory position of Geography in Scottish education.

'In summing up their conclusions the writers of the Report stated that, whereas in England 35,000 candidates offer Geography as a subject for the school certificate, less than 200 candidates in Scotland present it for the Leaving Certificate, and they contend that Geography should hold a position in Scotland analogous to that which it holds in England. The Departmental reply is that in Scotland all candidates for the Day School Certificate (Higher), of whom there are over 5,000, must include Geography in their curriculum, and that on the basis of population that number compares not unfavourably with the 35,000 candidates from the English schools. Now if the two certificates were approximately on the same standard it is obvious that the Department would have a case, but all the evidence goes to show that they are not. In the first place there is no guarantee that modern ideas regarding the scope and content of Geography have penetrated into a number of the schools. Those of us who have had anything to do with the preparation of a syllabus for the examinations in Geography held by the various examining bodies in England know the almost interminable discussions which take place before a draft scheme is finally adopted; for the *Scottish* Day Certificate the syllabus is drawn up by teachers often without geographical training, and approved by a department often without expert advice. We know that in some cases these schemes are thoroughly sound, but in others they are of very doubtful educational value. Again the English certificate is based on a four years' course, and the examination at the end of it, if passed on a sufficiently high standard, qualifies for University matriculation. The Scottish Day School Certificate is based on a three years' course, and the candidates are on the average between one and two years younger. The Department itself considers this amount of training inadequate for even the lower standard of the Leaving Certificate. We are far from suggesting or even desirous that the burden of examinations should be increased, but we feel bound to say that the examination for the Day School Certificate, which is not conducted by the Department but by the local authorities, does not necessarily show that Geography has been efficiently taught. We have heard of one case, for example, where the geographical part of the examination consisted of one question. "Through what waters would you pass in going from the Mediterranean to the Black Sea?" One other test may be applied to the quality of the work done by those who do not continue the study of Geography during the whole of their school career. My own experience and that of those who are associated with me in teaching Geography in the Scottish Universities is that we are compelled to spend a considerable amount of time to teaching parts of our subject which ought to have been but have obviously not been taught in school. I know from fourteen years' experience in an English university that the standard of the work done in the ordinary Graduation Class is lower, and is necessarily lower, than it would be if the bulk of one's class had already studied Geography up to the matriculation standard.

'Taking all these facts into consideration, we retain our opinion that, in considering the position of Scottish geography, the true basis of comparison is between the English School Certificate, where well over 50 per cent. of the candidates offer Geography as one of their subjects, and the Scottish Leaving Certificate, where the percentage of candidates offering Geography is only about four, and our contention is that such a state of affairs is thoroughly unsatisfactory.

'Our belief that all is not well with the teaching of Geography in the first years of the post-primary course is confirmed when we take into consideration the position in the advanced classes. From figures supplied by the Department we learn "that the number of schools conducted under the Secondary School (Scottish) regulations, which have courses including five and four years of Geography study beyond the primary stage, is 36 and 7 respectively. In addition there are 35 schools which

prepare candidates for the Leaving Certificate examinations in Geography in combination with another science at the end of a course extending as a rule to five or six years." That is to say that out of 78 schools which have Geography courses extending to four years and over only 2·6 candidates per school are presented for the Lower and Higher grades together in the Leaving Certificate. Indeed, with regard to the higher standard the position, despite the optimism of the Department, appears to be steadily growing worse. In 1927, of the total number of candidates offering Higher Geography, 62 took it as an optional subject under the new regulations, and a small number, probably about 20, took it as an additional subject under the old regulations (this latter figure was not supplied by the Department, but it seems safe to assume that about 80 offered Geography on the higher grade in that year). In 1928, when examinations under the old regulations had ceased, there were 75 candidates under the new regulations. If we bear in mind the fact that a few years ago there were over 150 candidates for the Higher Certificate, even though it counted only as an additional subject, the seriousness of the position is manifest. The only ray of hope—and it is but a feeble one—is that the number of candidates taking Geography on the lower standard has increased from 76 in 1927 to 127 in 1928. The Department claims that the total presentations in Geography for the Higher Leaving Certificate are now actually more numerous than they were under the old regulations, but this is true, and only true, if we compare the number taking Higher Geography under the old regulations with the number taking it at the higher and lower stages together under the new. To say that this slight increase in numbers accounted for by an increase of lower grade work indicates a marked stimulus to the subject is a misuse of language.

'We have next to consider the reasons for what appears to be a great lack of geographical interest in the Scottish schools. In the first place the necessity for appointing specialists in Geography has apparently not been appreciated in Scotland, and the teaching of the subject has often been relegated to teachers without any special preparation for their work. But, although this is so, we believe that the number of qualified teachers is sufficient to train a much larger number of pupils than are presented for the Leaving Certificate, and a number of these teachers have already complained to us of the small amount of encouragement they receive in their efforts to develop the subject in their respective schools. It is only here and there where an enthusiastic teacher is backed by a sympathetic headmaster that the results are really satisfactory. In many cases even where Geography is carried to a fourth and fifth year its study is casual, because the candidate is well aware that it is not to be used for examination purposes. Again I think we are justified in our belief that Geography does not always receive sympathetic consideration from the Department. In our report we remarked that opposition was sometimes incurred from inspectors whose university career did not include Geography, and who consequently tended to favour other sciences. It is difficult to accept the Department's assurance that our assumption is groundless in view of the instances which sometimes come to our notice of objections to geographical teaching made by individual inspectors. Even headquarters is not absolutely free from suspicion. The training college authorities at Aberdeen have been forbidden to allow students in training to take the graduation class in Geography out of college hours, though attendance on the class of English in college hours is permitted to those who have not already taken that subject. But at the back of all reasons for this neglect of Geography lies the fact that the subject has never been given a fair chance by the Department. Formerly it could only be taken as an additional subject in the Higher Leaving Certificate. To-day it is handicapped by the fact that it must be taken along with a science, and is not allowed to hold an independent position. In most boys' schools at least, physics and chemistry form the usual combination, and these work into one another and demand less time than geography and another science would. In practice, indeed, the custom is to devote to Geography less time than to other half subjects, while in fact it requires more. We are strongly of opinion that the position of Geography cannot be regarded as fully established until a place has been found for it as a whole subject. For such a course, indeed, there is ample justification. Educationally Geography occupies a special position linking up as no other subject does the scientific and humanistic aspect of intellectual activity. Its value in the training of the future citizen is equally great, and more especially in the training of those who do not intend to take a university course. Here I may quote from the Report: "Geography with History offers the only means whereby pupils can be given that groundwork of precise facts which must underlie sound judgments on the national and international problems

that confront the citizen of the complex modern world." We cannot teach world politics in schools, but we can give boys and girls in the advanced stages of their school courses an adequate knowledge of those geographical facts upon which the solution of so many important matters must ultimately depend. The failure of the Department to provide a much larger number of pupils with this preliminary knowledge is, in our opinion, much to be regretted.

'The Department's reply to the Report concludes: "It is probably in the meanwhile inevitable that the treatment of this, as of other individual subjects, may appear inadequate to those who are especially interested in them, but who may not have a full opportunity of appreciating the strength of competing claims or the magnitude of the task which pupils have to face in the whole range of their school work." Our claim is that the very small percentage of candidates taking Geography in the Leaving Certificate shows that the treatment of the subject not only appears to be, but is, inadequate, and that the English experiment has shown that it is possible to give Geography a much more important position without interfering in any way with the needs of a sound educational system.'

Dr. James Walker, Lecturer on Geography to the Glasgow Provincial Committee for the Training of Teachers.—'From what we have just heard from Mr. McFarlane, and in particular his interpretations of the comparative figures with which he has dealt, I am afraid only a very blind optimist can find any great satisfaction in the position of Geography to-day or any real evidences of development or progress.

'Mr. McFarlane has shown that there has been a falling off in the numbers professing the subject for examination, and that under the existing system, with its restrictions and conditions, these numbers are not likely to be satisfactorily augmented. Apart from numbers, however, there is another and important side to this question, and it is this: Under the present conditions is the quality of the teaching of Geography in schools likely to be improved so that the subject will take its rightful place in the curriculum? To this question I will give brief attention.

'In the primary stage of the school (*i.e.* up to the normal age of 12) Geography is a compulsory subject. At this stage, up to the present, there has been admittedly much good teaching, though the extraordinary and continued desire on the part of many teachers to stress the symbol at the expense of the actuality has greatly detracted from a proper appreciation of the value of the subject. Though this defect in our teaching may be passing, yet it is still too much with us, and I am of the opinion that no other single factor has had a more damaging effect on the place of Geography in school than this persistence in the glorification of the printed word, the name, the black dot and the red line on the map, for it has been felt that if the learning of names and the positions of dots is all that Geography means to the child or to the teacher, then it is worthy of no great consideration in any scheme of education. And what of the future? From Jordanhill Training Centre there passed out this year several hundreds of young graduate teachers who will take up work in the elementary departments of schools. Of these—and this is the point which I wish to stress—a very small percentage—less than 10 per cent. in fact—have done any study of Geography since they were at the intermediate stage themselves (*i.e.* since they were 15). Years have elapsed since then, and their present state is one of profound ignorance. These, and such as these, are being let loose upon an unsuspecting Scotland, and will soon constitute the bulk of our young teachers in the country; and one can quite well conjecture what the results will be, for a teacher may know the subject matter and yet not be able to teach it, but no one was ever yet able to teach a subject the facts of which he did not know.

'The age of the graduate teacher is at hand, and it is well; but we must remember that in teaching the nature of the degree is vitally important in determining the efficiency of the teacher. A graduate teacher to-day in our primary schools who has not taken Geography as a university subject is not so well equipped, and is therefore less likely to do good work in this subject, than the non-graduate teacher of yesterday, for provision was made for some instruction in the subject matter for the non-graduate, while none is made for the graduate. To improve conditions in this respect I would make two suggestions:—

'(1) An opportunity should be given to all pupils in secondary schools who intend to become teachers to continue the study throughout their whole course. (2) The value of the subject in their professional work should be clearly pointed out to all such student-teachers when they enter on their university course.

'This is important, since our main hope for the subject must lie in an increasing number of teachers who have been trained to appreciate the value of the subject as an instrument of education. (In this respect Glasgow University is doing good work, and a steadily increasing stream of students with Geography as a degree subject is passing from Gilmorehill to Jordanhill.)

'From the primary stage the pupils pass to :—

'(*a*) The Advanced Division Course, which extends for two or three years, or

'(*b*) The Secondary Course, which leads to the Leaving Certificate—a five or six-years' course.

'The Advanced Division Course was instituted on the suppression of the Intermediate Course, and was intended to cater for what we may call the non-academic boys and girls, who were not going to the university for example, but who were leaving school at 15 to take up work in commercial, industrial and other concerns. Even in the eyes of the Scottish Education Department these courses have not yet justified their existence, for in the *General Reports for the year* 1927 *on Day Schools by His Majesty's Chief Inspectors of Schools* they are critically referred to as following too closely the traditional intermediate curriculum. In commenting on this statement the editor of the *Scottish Educational Journal*, who was himself an experienced teacher, says : "If this becomes general we cannot see any great future for advanced divisions."

'In fairness, however, to those who instituted these courses, I must admit that, rightly conceived and rightly worked out, such courses afford great possibilities for good work, and particularly so in regard to Geography. In the freedom which they give to the teacher the materials which this subject offers, and the nature of the problems which it sets, may well be used to form an admirable link between the school and life and work, and to afford valuable means of developing and guiding the sympathies and mental powers of the pupils, and the consequent establishment of that basis of a well-balanced outlook which will enable them to fill with credit their place as citizens of their country and of the world. But the time is not yet, and what we have in actuality is that indeterminate, mongrel course which appears to have all the weak points of the old Intermediate Course and none of its merits. And the certificate (Day School Certificate, Higher) which is awarded on the completion of the course, is just as indeterminate, but I have little hesitation in saying that, so far as Geography is concerned, it does not demand the same proficiency as did the old Intermediate Certificate.

'Of the Secondary Course, where, with a grouping with another science, Geography may be taken on a lower or higher standard, nothing need be added to what has been already said, or what has already been printed in the Association's Report of 1927.'

Mr. A. Stevens, Lecturer on Geography in the University of Glasgow.—'The letter of the Scottish Education Department is so tenuous in its matter, and Mr. McFarlane's treatment of it so thorough, that I do not feel called on to make further comment upon it. On the general question of the unsatisfactory state of the study of Geography in Scottish schools, however, the universities have their point of view, which demands expression and consideration.

'For a considerable time there has been an output of skilled teachers of Geography, to whose equipment the universities contributed the necessary scientific knowledge, and these teachers are not being absorbed as specialists in Geography by the schools. The University of Edinburgh has had for a good many years a diploma in Geography which is recognised by the Scottish Education Department as a qualification under Chapter V. In Glasgow and Aberdeen there are functioning honours schools of Geography, and Edinburgh is likely to establish such a school in the near future. There is ample provision, therefore, for the training of all the specialist teachers of Geography the country would require if the subject had its due recognition in the school curricula.

'The school teaching of Geography reacts in many ways on the university departments, and in particular it affects the number and calibre of recruits for the university honours schools. A considerable and steady demand for teachers of Geography would ensure an ample supply of students of high attainment and intelligence for the university honours classes, just as it does in the case of physical sciences. The first honours graduate of Glasgow in Geography, who is a trained teacher, is now unemployed, and later products of that school have failed to secure "Chapter V. posts" in their subject in Scottish schools ; although several have secured research appointments and university posts in England. For the encouragement of geographical

research and the maintenance and improvement of geographical teaching it is essential that there should be an adequate stream of students into the honours schools from which the very best may be selected for research and higher posts. If the Scottish schools do nothing to hinder such a stream it is to their discredit that they do less than nothing to foster it.

'Mr. McFarlane has already referred to the handicap imposed on university teaching of Geography by ignorance of the subject among first-year students. The students labour under the disability right to the end of the honours courses. Since it cannot be permitted to lower the honours standard of attainment it makes the work of the student unduly arduous. Co-operation between school and university along this line is surely axiomatically desirable within the group of subjects suitable for the school curriculum, whether on account of the contribution they make to the mental equipment of future citizens whose formal education ends with the school, or because of their aptness to provide mental discipline for the youthful intelligence. It is not, and need not be, argued that the schools should teach Geography throughout the secondary course because the departments of Geography at the universities wish it. A grasp of the content and method of modern geography alone is requisite to realisation of the unique and necessary contribution it can make to the training of the citizen and the valuable (and orthodox) gymnastic it provides for the mind. And it is the fact that, whether they say *yea* or *nay* to the claims of Geography, the bodies, including the Scottish Education Department, responsible for the curricula in the secondary departments of Scottish schools do not show in any way that they command the necessary and sufficient knowledge and insight to judge of the proper place of Geography in these curricula.'

Dr. R. R. Rusk, Principal Lecturer in Education to the Glasgow Provincial Committee for the Training of Teachers.—'While I hold no brief for the Scottish Education Department, I am prepared to undertake the defence of the Department's reply. What the Section requires, I maintain, is a sense of perspective. Other Sections might likewise adopt the same attitude regarding the position of the teaching of their subjects in the schools. I contend that Geography in Scotland is not in the parlous condition the report suggests. Secondary teachers of Geography in Scotland require an honours degree in the subject; teachers in Advanced Divisions—equivalent to central schools in England or the modern schools of the Report on the Education of the Adolescent—must have taken at least one degree class in Geography; and it is possible that in the future the Department will only accept for training degrees comprising certain specified subjects of which Geography will probably be one. So far as I can make out, the number of students entering training centres with Geography in their degree is increasing, and that is a favourable sign, as they would return to the schools to teach the subject.

'The key to the position of Geography in Scotland is in the Advanced Division. The section should provide schemes of work in Geography for this stage of school life—the teachers would welcome them and the Department doubtless approve of them, and members of the Section should prepare appropriate text-books written from the Scottish standpoint and emphasising the economic geography of Scotland. Lecturers in Geography should avail themselves of opportunities for addressing Educational Institute of Scotland meetings of teachers and should regularly contribute to the *Scottish Educational Journal* articles on Scottish geographical topics. Every means should be adopted to enlist the sympathy and interest of the teachers. Complaints against the Department tend to become defence mechanisms set up by teachers who do not desire to adopt modern methods and do progressive work; the Section should rather devote itself to constructive proposals.'

Mr. James Hunter, of Hyndland Secondary School, Glasgow.—'I am in substantial agreement with much of the criticism Dr. Rusk has expressed. The statement has been made that students enter the Geography classes at the university in an ill-prepared condition. It should not be forgotten, however, that university authorities might remedy this for themselves by demanding as an entrance qualification the possession of the Lower of Higher Leaving Certificate in Science (including Geography). I think that the speakers are exaggerating the difficulties and discouragements of the situation. In my own school there has been a marked development in the teaching of Geography. Twenty-eight pupils in the fourth year are this session studying Natural Science with a view to the Higher Science Leaving Certificate, and of these sixteen had chosen Geography as one of the two

subjects of the course. This contrasted with only twenty-two pupils whose course included Physics. In addition there were about sixteen pupils preparing for the Lower Grade Leaving Certificate (including Geography).

'In my opinion the Section ought not to make extravagant claims for the subject. I do not believe that if the question were submitted to an audience of Scottish teachers you would receive the support you expect. The whole question is one of the conflict of studies in a complex modern school organisation. Few would agree to the proposition that Geography should be regarded as the equivalent of, or as a substitute for, Mathematics, or to the statement made by a previous speaker that Geography was entitled to a larger allowance of school time than Physics. Geography is indeed a derived science, and presupposes a fair knowledge of both Mathematics and Physics. In my opinion it is not demanding too much to ask that a pupil should profess Lower Grade Mathematics in his Leaving Certificate course.

'The Section has not fully appreciated the recent change in the conditions of award of the Certificate of Fitness, by virtue of which the Higher Leaving Certificate in Science (including Geography) will now be regarded as a higher pass for the purpose of admission to the universities, provided that it is accompanied by a pass in Lower Mathematics. I believe that this will in many schools inevitably lead to such an increase in the number of pupils studying the subject of Geography as to remove the reproach which formerly existed. On the whole I consider the Departmental reply practically unanswerable, and I would suggest that, while the section might hopefully await developments in the immediate future, it should also endeavour to secure the recognition by the Department of the subject of Geography as an essential part of the curriculum for every secondary school pupil, having a status equivalent to that of History, and with a definite minimum of school time allocated to it by those whose course does not include the Higher Science Leaving Certificate (containing Geography).'

Dr. D. C. T. McKie, Headmaster of Bonnington Road Central School, Edinburgh.—'While agreeing with some of the previous speakers as to the unsatisfactory position of Geography in Scottish schools, I do not agree with those speakers who attribute the blame wholly to the Scottish Education Department. Among the factors to be considered are the following :—

'1. The position of the subject in our universities.

'2. The position of the subject in various professional examinations.

'3. The neglect and ignorance of the subject shown by many teachers.

'These, added to the indifference to the claims of the subject shown by the Scottish Education Department, have led to the generally unsatisfactory position in which Geography is placed to-day. It is unnecessary to say here that the teaching of Geography has developed enormously during the past twenty-five years, but it is sometimes forgotten that only those who have studied the subject closely know how great the development has been. Geography as taught to-day and Geography as taught twenty-five years ago are entirely different subjects, and consequently those who were trained in the old way do not understand the claim made for modern Geography, and from their point of view naturally protest against the absurdity of placing Geography on a level with the standard subjects of the old curriculum.

'While approving thoroughly of the claim put forward for a fuller recognition of Geography, I am of opinion that it is bad policy to make an attack on a Government Department on the ground of statistics. It seems to me that we are on much surer ground when the claim is made for the recognition of Geography on the ground of its educational and cultural value.

'We should continue to press this claim (1) on the Scottish Education Department.

'This is the more important at present when courses are being considered for the new Advanced Division schools. It has been accepted that these courses are to be non-academic, and although they are for two years only they are to be regarded as equivalent to the first two years of any secondary course. Geography might well claim to be given a more prominent place in these practical courses, but so far only two periods per week are being allotted.

'(2) On public bodies. Many of these are specially interested in Geography through commerce and industry and they might be induced to give an important place to the subject in their professional examinations.

'(3) On educationists. Teachers themselves are not wholly free from blame. I do not refer only to those of the older school, but some of the younger teachers who have been trained in the modern methods are attempting to do too much. In the limited time allotted to the subject—usually two periods per week—care must be

taken not to cover too much ground. To attempt to present all the modern aspects of Geography in the ordinary school curriculum is like trying to put gallons of liquid into a pint pot.

'Consequently many pupils are not being trained in a satisfactory way, and when they are examined by inspectors who follow the tradition of the elders they show up badly, and "modern Geography" is condemned.

'I think that if the committee to whom this matter was referred for consideration were to work along these lines it might lead to a more satisfactory conclusion than to indulge largely in destructive criticism.'

Dr. Cyril Norwood, Headmaster of Harrow School, President of Section L.—'So far as I can tell from a first reading, the difference between the Association and the Education Department is due to a difference in their respective conceptions of Geography. It is difficult for those who are not abreast of the modern teaching of the subject to estimate fairly the claims advanced on its behalf in the present day. It can perhaps be fairly claimed that Geography had made more advance south of the Border, for it can be taken as a full subject in the School Certificate by all boys and girls at the age of sixteen, and again as a full subject in all examinations for the Higher Certificate two years later, counting either as a humane or a scientific subject. It is therefore possible for students to carry their work to a high level before going to the university.

'Geography is a subject of special value in the present day, when in Scotland, as in England, the secondary schools were filled by greatly increased numbers who were not entirely suited by the courses of study at present existing. For the ordinary average boy or girl no study presents an easier means of enabling them to play their part as citizens in the modern world, to understand things in general and to read the newspapers with intelligence. It is also a vitally important part of the equipment of the teachers with whom lies the training of the great bulk of the population who will not carry their academic studies far.

'But the subject as understood to-day cannot be taught on a meagre allowance of time, and two periods a week cannot give the results which geographers seek and may fairly demand. I cannot say the geographers are always reasonable in England, any more than in Scotland, and I cannot go with them when they claim that on the same syllabus the subject should count either as one of the humanities or a science in one and the same examination. But they have made great and deserved progress in the south largely through the enthusiastic work of a small group. They have devoted themselves mainly to the preparation of suitable text-books, to the composition of modern syllabuses for different types of school, and to proving their claims by reasoned arguments. The best way of advancing the study is not only to tell people what to do but to show them how to do it.'

Mr. W. J. Gibson, C.B.E., late Headmaster of the Nicolson Institute, Stornoway.—'In offering a word or two of comment on this interesting statement on the position of Geography in Scottish schools, I speak not as a geographer but as a schoolmaster.

'The main difficulty in the way of its finding a fully recognised place as a higher subject in secondary schools is the crowded condition of the curriculum—a subject late in claiming admission fares badly. The only cure for this is steady missionary work carried on by the members of the Geography Section among the public, and particularly among schoolmasters and schoolmistresses, pressing upon them the educational value of the subject as a combined science and humanity. This, if I may venture to make the suggestion, will be best done persuasively rather than controversially.

'The attitude of the Scottish Education Department has been, so far as my experience indicates, sympathetic both in the consideration of submitted schemes and in the welcome given to fresh ideas. When they assure themselves, as they do, of the fitness of the teacher, and of the provision of adequate time and equipment, and provide a suitable examination of sufficiently high standard, they have, I think, done all that can be fairly expected of them by the geographers. The rest can be won only by convincing those in authority in the schools.

'From the point of view of the geographical instruction of the general body of the people, more serious than the dearth of higher candidates is the feature of the present position referred to in the Report on page 2 in the words: Geography "has actually disappeared beyond the third year's curriculum in many secondary schools." The

university student whose school course has such a gap in geographical study naturally feels discouraged from including the subject in his arts course, or, if he does include it, he is so out of touch and has so far forgotten what he learned in his first three years, that his university work in the subject is carried out under considerable hardship for himself and more than a little difficulty for his university instructors.

'The value of the subject as a means of widening the individual outlook, and of providing a needed equipment for citizens in a democratic State, who will have to form judgments on international as well as national questions, makes it highly important that it should be taught to all pupils throughout the whole secondary course, even if only a small minimum of time can be allotted to it. My personal opinion is that even in the crowded curriculum of to-day there might still be spared, for all pupils, $1\frac{1}{2}$ hours per week in the fourth year and one lesson a week of three-quarters of an hour in each of the fifth and sixth years.

'The work attempted in such a small measure of time would necessarily be small in amount, but it could be sound in method as far as it went. It might include some individual observational work in meteorology, some study of land forms in the field, the power to read a map, such hint of survey methods as would be given by a few plane-tabling exercises, such introduction to the regional outlook as would give insight into the effects of winds and moisture and soil on plant and on animal production, and on the results of these, along with the occurrence of minerals, on the distribution and industries of peoples and their interchange of commodities. Narrow as the ground covered would have to be, the intelligence would find good material to work upon, and there need be nothing acquired that would have to be unlearned at a later stage.

'Every pupil completing a secondary course would in this way be kept in continuous contact with the subject until he reached the university and had an opportunity of extending his knowledge by including Geography in his Arts Course. While desirable that as many students as possible should so include it, those in a position to influence the choice of subjects made by intending teachers should encourage all these to give Geography a place in their work for the pass degree ; for it is on them that the pupils of the primary schools, of Advanced Divisions, and of many of the junior classes in secondary schools—that is, almost all of our future citizens—will have to depend for such presentation of the subject as will exercise their intelligence and arouse their interest.'

The President of the Section, reviewing the main points of the discussion, thought that a comparison of the statistics contributed on both sides showed that a good deal remained to be done before Geography was accorded in Scottish schools the position which he had advocated for it in his Address to the Section (p. 99). Illustrations had been given of what was desirable and practicable, in Scotland as well as elsewhere ; and he noted with satisfaction the assurances of the Department that reasonable encouragement was given to the teachers who initiated experiments in their own teaching. It was for the teachers to take the Department at its word, and put forward their suggestions and the results of their experience in practical shape and actual examples. If text-books and source-books were deficient, it was for the teachers and their advisers to produce better ones. If methods were inefficient, and geographical training inadequate, it was for the universities and training colleges to revise and expand their geographical instruction ; and for those who selected the teachers and assigned them to geographical teaching, to insist on thorough preparation and active appreciation of Geography as an 'outdoor' subject as well as a training by book-work.

Everyone admitted the congestion of the time-table, and it was the misfortune of a comparatively new subject like Geography that it 'found the coach already full,' and had in the past to be content with a seat 'on the knees' of some other subject such as History or Geology, already established there. In his own view, whenever the opportunity came for rearrangement of the whole convoy, the proper place for Geography would be found not 'inside the coach' at all, but on the box seat.

INBREEDING IN JERSEY CATTLE.

THE POSSIBILITY OF YIELD AND QUALITY OF MILK BEING INHERITED IN A SEX LINKED MANNER.

BY

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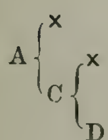
For some time past the methods employed by breeders in the construction of various breeds of commercial livestock have been studied in this department. The analysis of the various breeds has been made by means of Wright's coefficient of inbreeding, which in essence is based on Galton's Law of Ancestral Inheritance, with this important addition, that inbreeding cannot be considered to have full genetic effect on the homozygosity of the animal unless the ancestor to which the animal is inbred appears in the pedigrees of both the sire and dam of that animal. Figure I gives examples of Wright's coefficient. The two lower pedigrees show that, although in both of them the common ancestor, x, is a grandsire and a great grandsire, inbreeding only occurs in the left-hand pedigree since, on the right-hand one, x does not appear as an ancestor of the dam of the individual.

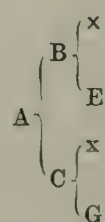
FIGURE I.

(A) *Examples of Coefficients of Inbreeding (Wright's).*

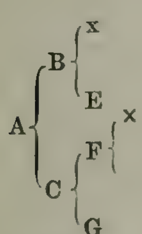
(B) x = Common Ancestor.



Sire to daughter coefficient 25.

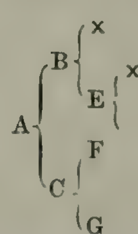


Half-sister to Half-brother coefficient 12.5.



Coefficient 6.25.

Common Grandsire and Great Grandsire.



Coefficient nil.
The common ancestor appears on only the sire's side of the pedigree.

$$\text{Wright's Coefficient } F = (\tfrac{1}{2})^{n+n^1+1}(1+fa)$$

n and n^1 represents the number of generations which the common ancestor is distant from the sire and dam respectively. Fa is the coefficient of inbreeding of the common ancestor.

TABLE I.

THE ENGLISH JERSEY BREED—ITS COEFFICIENTS OF INBREEDING BY TEN-YEAR PERIODS.

10-year Period.	Breed.		Bull Calves.		Cow Calves.	
	Coeff. %.	P.E.	Coeff. %.	P.E.	Coeff. %.	P.E.
1876–85 . .	2·613	±·259	3·658	±·429	1·568	±·286
86–95 . .	2·290	±·247	2·562	±·367	2·018	±·330
96–05 . .	2·859	±·269	3·110	±·399	2·608	±·367
06–15 . .	3·158	±·286	2·623	±·367	3·693	±·429
16–25 . .	3·913	±·313	3·562	±·429	4·264	±·456

In Table I the result of the study of the English Jersey breed of cattle are shown. There is no great degree of inbreeding. Further discussion of this will be published elsewhere.

Dr. J. S. Gordon, in his Presidential Address to Section M, stressed the need of standards of production before livestock improvement could advance much further. This was emphasised in the discussion which followed, particularly by Prof. R. G. White, who stated that herd books as at present constituted, though they had served a useful purpose in the past, required to add information concerning the performance of the ancestors of the individuals if they were to be of continued benefit.

With a view to finding out whether there was any connection between inbreeding and productivity, especially milk yield, a list was drawn up of the pedigreed English Jersey cows, born between 1916–20 inclusive, which in one lactation of less than 365 days gave over 10,000 lb. of milk. This list was taken from the Register of Dairy Cows with authenticated milk records compiled and published by the English Ministry of Agriculture and Fisheries. Ninety-eight animals were obtained for this period. Only thirty of these were traced to the Herd Book from the date of birth and owner's name, as the pedigree numbers are not given in the Register. From the English Jersey Herd Books for 1923–24–25 a list of cows was made up which gave 10,000 lb. in less than 365 days. This gave an additional thirty cows. The coefficients for these sixty cows were then tabulated.

The pedigrees of these sixty cows gave an average co-efficient of only 1·845, as compared to the breed average for the corresponding ten-year period of 3·913±·313, and for the cows of the breed born in that period of 4·264±·456. These differences are appreciably greater than four times the probable error, and may therefore be considered to be significant. Nine of these sixty cows had coefficients greater than the average of the breed, ranging from 3·95 to 12·65. Twenty-seven had a coefficient of less than 1·0.

This finding is not in accord with the work of the Maine School (Pearl and others, 1919, Gowen and Covell, 1921–1, 1921–2, and Gowen, 1924, Chapter VII), who state that high producers are equally inbred as the low producers. However, Gowen (1924, p. 121) shows that in the American Holstein the sires with no advanced registry daughters are somewhat more inbred than the sires of advanced registry daughters. The findings of the Maine School are, however, barely comparable to those in this paper, as Pearl's coefficient is employed, which is purely objective and has nothing whatever to do directly with the gametic constitution of individuals.

McPhee and Wright (1926) found no material difference in the amount of inbreeding between the Beef and the Dairy Shorthorns. They did not study the high yielders.

The examination of the pedigrees of animals in two noted Jersey herds confirmed this difference, noted as regards the breed as a whole. These were the Godinton herd and the herd of Mr. J. S. Gordon in Northern Ireland.

One reason why the high yielders were less inbred than the average of the breed was because the average cow of the breed was more inbred to a bull who was all powerful some thirty years ago. The arrival of accurate milk recording on a large scale within the past fifteen years has, however, altered the standards somewhat with the quite natural result that the concentration of the blood of a bull of the older standards does not help breeders to obtain in their animals the requirements of the present day. This will be further discussed in a later paper.

Sex Linkage and Milk Yield.

Some ten of the sixty high producers were more inbred than the average of the breed as a whole. Examination of these pedigrees along with those of the two herds already mentioned led the writer to believe that there was an indication that one or more factors governing the yield of milk, and perhaps quality, might be sex linked. Inquiry of several breeders strongly confirmed this idea. Several herds proved to be working along these lines.

The inheritance of milk must depend on many genetic factors. Gowen has shown that yield is definitely correlated to such heritable characteristics as weight, body length, body width, body girth, hip height, shoulder height and rump length. In addition various other heritable characters which are more difficult to measure undoubtedly affect the total yield. Amongst these are the size and shape of the udder, the size and tortuousness of the milk veins, the 'touch' of the hide, temper of the individual, &c.

Many of these characteristics are governed by entirely different factors in the germplasm, and while it is not reasonable to expect that the majority of the factors are inherited in a sex linked manner, it is at least permissible to speculate upon the results were one or two of the more important inherited in this manner. In cattle the male is the heterogametic sex and, if the above assumption is made, then inbreeding to a prominent and proved sire through his sons would have no effect in concentrating the sex linked qualities of that sire. To a less degree inbreeding to a prominent cow through her daughters would not be so productive as inbreeding to her through her son or to the bull through his daughter. Thus a statistical analysis of inbreeding might give an entirely erroneous idea of the situation.

Figure II.

Inbreeding and Sex Linkage.

In cattle the male is the heterogametic sex.

(1)

Mystole Veronica vol. 30, p. 88
- sire
  - ——
  - g. dam
    - Violettes Aurelius.
    - ——
- dam
  - Violettes Aurelius.
  - ——

Coefficient to Violettes Aurelius = 6.25.
Sex linked character present from Violettes Aurelius.

(2)

A . . .
- sire
  - Violettes Aurelius.
  - ——
- dam
  - g. sire
    - Violettes Aurelius.
    - ——
  - ——

Coefficient to Violettes Aurelius = 6.25.
No sex linked character present from Violettes Aurelius.

The two pedigrees in Figure II are an example of this. The first shows sex linkage, and was a type of pedigree found amongst the few inbred high producers. The second, though equally inbred to the sire Violettes Aurelius, does not show sex linkage.

The writer is indebted to Dr. H. Corner, of Brook House, Southgate, London, for the direction of his attention to this. Dr. Corner was breeding his herd of Jerseys along these lines with notable results when unfortunately, owing to an outbreak of foot and mouth disease, the herd had to be destroyed. Miss Robertson (1921) contributed a paper to the *Journal of Genetics* from statistics of a herd of Kerry cattle which had been recorded daily since 1904. The figures and suggestions in her paper may perhaps be accommodated by this suggestion. The practice adopted in this herd, when fresh blood is deemed necessary, is to introduce it by way of the female line.

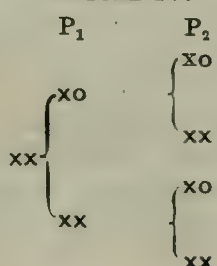
Figure III shows the line of transmission of a character inherited in a sex linked manner. The sex linked factors are marked by a thick line. Where the contribution is through the dam it is designated by a dotted line, for she may be heterozygous for the sex linked character, and therefore the contribution in a population should average at rather over half of that marked by the thick line through the sire.

FIGURE III.

Inheritance of a Sex Linked Factor in Cattle.

Alternatively the line of sex linked inheritance might perhaps be better understood by the following diagram.

FIGURE IV.



Since a bull contributes no x chromosome to his sons, all contribution of a sex linked factor to the sons' progeny must be traced through their dams. Therefore the paternal grandparent contributes no sex linked character to his granddaughters.

It will be noticed that half of the sire's pedigree makes no contribution, however good it may be. This is the side that is frequently most emphasised. Altogether, in the fourth parental generation only half the ancestors need be considered in the examination of a pedigree from this point of view. While, in a way, the sire's contribution to the heifer is the more important, it is only so because it is the more definite. The dam has a greater accumulation of blood lines to draw upon, and if there are several sex linked factors involved, may certainly make the bigger contribution on the average.

On making a close study of the work of Gowen and others at Maine in search of facts which might disprove this hypothesis the writer was unable to find anything definite in this direction. On the contrary Gowen, in his book (1924) dealing with American Holstein Friesians from the Advanced Registry, gives figures showing the correlations between daughter and parents and between daughter and grandparents. Table II tabulates his results, and is drawn chiefly from pages 155, 188, 224, 252, 300, 309, 319 and 327.

TABLE II.

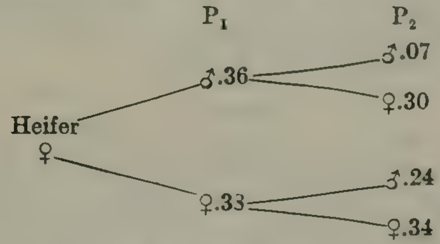
SHOWING CORRELATION COEFFICIENTS OF HEIFERS WITH THEIR PARENTS AND GRANDPARENTS (FROM GOWEN).

		Yield.	P.E.	Butter Fat %.	P.E.
Half	Same sire . . .	·362	±·015	·374	±·015
Sisters	Same dam . . .	·381	±·033	·221	±·036
Daughter to:					
Paternal Grandsire. . .		·070	±·014	·176	±·014
Paternal Grand-dam . .		·297	±·014	·336	±·014
Maternal Grandsire . .		·244	±·016	·224	±·016
Maternal Grand-dam . .		·344	±·021	·258	±·022

Thus, while the parents contribute about equally, there is considerable variation in the grandparents, that of the parental grandsire being considerably and significantly less than the other grandparents. That the correlations are small does not greatly matter. The difference exists, and, as far as the writer is aware, Gowen has made no attempt to explain it. This table may be represented diagrammatically in Figure V.

FIGURE V.

Showing correlation of milk yields with parents and grandparents from Table II.



This squares fairly well with Figures III and IV, showing how sex linked characters are inherited and how the paternal grandsire has no influence in the matter.

Table III shows the correlation figures for cousins by the same grandparents grouped according to the specific grandparent. This forms a useful confirmation of the previous table. The effect of the paternal grandsire in this case is less than the probable error, and may therefore be considered to be nil. The figures for this table are also taken from Gowen's work. For interest the correlations of full sisters and dam to daughter are also added.

TABLE III.

FURTHER CORRELATION COEFFICIENTS OF RELATED COWS.

	Milk Yield.	Butter Fat %.
Cousins by Common :		
Paternal Grandsire	·005 ± ·029	·119 ± ·029
Paternal Grand-dam	·171 ± ·045	·214 ± ·044
Maternal Grandsire	·206 ± ·020	·216 ± ·020
Maternal Grand-dam	·234 ± ·044	·244 ± ·044
Full Sisters	·548 ± ·027	·464 ± ·032
Mother to Daughter	·497 ± ·021	·413 ± ·023

Further, Pearl, Gowen and Miner (1919) in their work on the American Jersey, give a list of sires in order of their sons' performances as parents of productive heifers. While certain bulls came out of this study to their credit, there are what the authors call 'certain disappointments.' The greatest of these are the sons of Hood Farm Torono 60326, who, without exception, lowered the production of their daughters. Hood Farm Torono clearly led amongst the list of sires in increasing the milk production of his progeny over that of their dam. There are also other such 'disappointments.' The sons of imported bulls make a rather better showing, but here again there are similar cases, the male progeny of Noble of Oakland being one of them.

Gowen (1925), working with the Guernsey breed, shows how great is the variation in the yields between the sire's daughters and his son's daughters. He states, 'Thus we could expect from any given grade of sire, whether his daughters were high or low, sons which would have daughters ranging from the highest to the lowest producers in the breed.' Again 'The variation of the sons' daughters in production is also practically the same as that of the whole breed.' The point to be gathered from this work is that, while the sons tend to revert to the average of the breed, this is not nearly so marked in the daughters. Thus further evidence is obtained in favour of the hypothesis that one or more of the factors governing milk production, both yield and butter fat percentage, are inherited in a sex linked manner.

*   *   *   *

This is partly hypothesis, and while the premises on which it is based are exceedingly suggestive they cannot yet be taken as absolutely sound. No valid grounds have been found upon which to disprove it, but the matter requires further investigation because, if the hypothesis should bear fruit, it ought to modify the practice of breeders to a considerable extent.

The reason for its inclusion in this discussion is because the writer is of opinion that the ideas and principles that activate enlightened breeders are always worthy of consideration, even though the scientist is unable to prove or disprove them. And in this case facts which support the theory of the practical breeder have undoubtedly been obtained. Statistics in themselves can prove nothing, but placed alongside tangible facts they become alarmingly suggestive.

THANKS.

The writer wishes to thank all those who have generously given that help without which the facts and figures would not have been assembled. To Mr. J. S. Gordon, of the Ministry of Agriculture in Northern Ireland, he is particularly indebted, for the study owes its origin to his ideas. Thanks are due to the Jersey Cattle Societies of both Jersey and England for the loan of the herd books, as well as for help in other directions, to the Ministry of Agriculture for the gift of the 'Registry,' and also to Mr. Bruce Ward for particulars about his herd. To Dr. H. Corner the writer is grateful for his suggestions and for his patience and forbearance throughout a lengthy correspondence.

And finally the writer gladly acknowledges the work of Mr. J. R. Brown, B.Sc. (Agr.), of the Nigerian Agricultural Service, who did all the statistical work, analysed the pedigrees and calculated the coefficients. The writer regrets that Mr. Brown was unable to conclude this investigation himself.

Summary.

1. In English Jersey cattle cows giving over 1,000 gallons in one lactation are found to be less inbred than the average of the breed.

2. A possible reason for this is that yield is not inherited in an entirely autosomal manner, but that one or more factors governing its production as regards both quantity and quality may be sex linked.

3. Examination of the pedigrees of the high-yielders supported this view as well as the experiences of certain practical breeders.

4. If this were the case, then the paternal grandsire would have little effect on the yield of his granddaughters.

5. Figures are quoted from the work of Gowen which show that the contribution of the paternal grandsire is significantly less than that of the other three parents.

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EVENING DISCOURSE.

ON THE STUDY OF POPULAR SAYINGS.

By Prof. Edward Westermarck.

Being the Frazer Lecture in Social Anthropology, 1928.

(*Abstract.*)

In the lecture I have been invited to deliver in honour of Sir James Frazer I shall take the opportunity to emphasise the importance of his writings from a point of view which is apt to be overshadowed by their more prominent merits as inexhaustible mines of facts and as storehouses of far-reaching generalisations and brilliant theories. When I set out to gain some personal experience of native customs and beliefs and made Morocco my field of research, 'The Golden Bough' drew my attention to many facts that otherwise, in all probability, would have escaped my notice. It offered suggestions and explanations, which were none the less valuable because they were not always applicable to the particular data that came under my observation. And it brought home to me the great lesson, never to rest content with recording the mere external modes of native behaviour without endeavouring, so far as possible, to find the ideas or sentiments underlying them. For this reason I desire to render homage to my great teacher by stating some general results of my experience as a field-anthropologist.

It has been said to be a difficult or hopeless task to try to discover why people perform rites and ceremonies, that directly one approaches the underlying meaning of rite or custom one meets only with uncertainty and vagueness. I cannot say that this view is confirmed by my own observations in Morocco, where I generally found the natives to have quite definite ideas about their rites. But the direct inquiry into these ideas is not the only way in which they may be ascertained. The most convincing information is often obtained, not from what the natives say *about* their rites, but from what they say at the moment when they perform them. To take a few instances. That the fire-ceremonies practised in Morocco, as in Europe, on Midsummer Day or on some other particular day of the year, are purificatory in intention is obvious from the words which people utter when they leap over them or take their animals over the ashes. The Moorish methods of covenanting, which always imply some kind of bodily contact, for example, by the partaking of a common meal, derive their force from the idea that both parties thereby expose themselves to each other's conditional curses; and the idea that food eaten in common embodies such a curse is very clearly expressed in the imprecation addressed to a faithless participant. These customs, and the sayings connected with them, have led me to believe that the very similar methods—such as a sacrificial meal—used by the ancient Hebrews in their covenanting with the Deity were intended, not, as has been supposed, to establish communion, but to transfer conditional curses both to the men and their god. That one idea underlying the Moorish custom of tying rags or clothing to some object connected with a dead saint is to tie up the saint, and to keep him tied until he renders the assistance asked for, is directly proved by words said on such occasions. This has suggested to me that some similar idea may perhaps be at the root of the Latin word for religion, *religio*, if, as has been conjectured, this word is related to the verb *religare*, 'to tie.' It might have implied, not that man was tied by his god, but that the god was in the religious ritual tied by the man.

While a saying uttered on the occasion when a rite is performed is apt to throw light on the meaning of the rite, there are other sayings that can themselves be explained only by the circumstances in which they are used. This is the case with a large number of proverbs. It has been said that the chief ingredients which go to

make a proverb are 'sense, shortness, and salt,' but the most essential characteristic of all is popularity, acceptance and adoption on the part of the people. Figurativeness is a frequent quality, but there are also many sayings recognised as proverbs that contain no figure of speech. On the other hand, there is hardly a proverb that does not in its form, somehow or other, differ from ordinary speech. Rhythm, rhyme, and alliteration are particularly prominent features.

The proverbs of a people may be studied from different points of view. In many cases their study has been the pursuit of philologists, who have been mainly interested in the linguistic aspect of the subject. But as a source of information on the language spoken by a people its proverbs must be handled with caution, as they may contain expressions which are not found in the native idiom, but belong to another dialect from which the proverb has been imported, or, as is often the case with Arabic proverbs, have been taken from the literary language, which in many respects differs from the modern vernaculars.

Another method of studying proverbs is to examine their diffusion. Peoples have at all times been taking proverbs from each other. Among the nations of Europe we find a very large number of identical, or almost identical, proverbs which obviously have a common origin. Very many of our proverbs have been borrowed from the Romans, who themselves had borrowed many of theirs from the Greeks, and another great source has been the Bible. Others have come from the mediæval monasteries, or been introduced into Europe by Jews or Arabs. The wanderings of proverbs are a fascinating study, but one beset with considerable difficulties. The resemblance between proverbs may have another cause than diffusion, namely, the uniformity of human nature, which makes men in similar situations think and feel alike. The real test of a common origin is not the mere similarity of ideas and sentiments expressed in the proverbs, but the similarity of formal expression, of course with due allowance for modifications that are apt to occur when a saying is adopted from another language and transplanted into a new soil.

There is a third way of studying proverbs, which is primarily concerned with their contents as a subject of sociological or psychological interest. That in the proverbs of a people are found precious documents as regards its character and temperament, opinions and feelings, manners and customs, is generally recognised. Lord Bacon said that 'the genius, wit, and spirit of a nation are discovered by their proverbs.' There may be some exaggeration in statements of this kind, as many of the proverbs are not indigenous. But on the other hand a foreign proverb is hardly adopted by a people unless it is in some measure congenial to its mind and mode of life; it may be modified so as to fit in with its new surroundings; when sufficiently deeply rooted it may in turn influence the native habits of thought and feeling; and if it does not succeed in being acclimatised in its adoptive country it will wither and die. As an illustration of the insight a people's proverbs may give us into its life I choose to read a brief extract from my collection of sayings relating to robbery, which I found among a tribe of mountaineers in Northern Morocco who carry on robbery as a genuine trade.

Not infrequently some of the proverbs of a people contradict the teaching of others. Such incongruities may be more apparent than real. Proverbs may have the form of categorical imperatives on account of their necessary brevity, and in such cases their one-sidedness has to be corrected by others dealing with particular circumstances that modify the general rule. Moreover, as people are not all alike one maxim may appeal to one person and another different maxim to another. And there is, further, the distinction between proverbs that represent ideals and others that are based on realities which do not come up to these ideals. But it must not be assumed that a people's proverbs on a certain topic always tell us the whole truth about their feelings relating to it. The Moorish sayings concerning women and married life may serve as a warning. They are uniformly unfriendly or thoroughly prudential, and might easily make one believe that the men are utterly devoid of tender feelings towards their wives. But here we have to take into account their ideas of decency. It is considered indecent of a man to show any affection for his wife; in the eyes of the outside world he should treat her with the greatest indifference.

Proverbs are not merely reflections of life but play an active part in it; and this functional aspect of the matter should also engage the attention of the student. Proverbs teach resignation in adversity, they give counsels and warnings, they are means of influencing the emotions, will, and behaviour of others, as they may influence one's own, whether they are shaped as direct commands, or are statements of some

experience drawn from life, or are expressions of approval or admiration or of disapproval or contempt. The exceedingly frequent use of proverbs in Morocco, as in other countries with a Semitic culture, bears testimony to their great social adaptability. The proverb is a spice by which anybody may add piquancy to his speech, it shortens a discussion, it provides a neat argument which has the authority of custom and tradition, it is a dignified way of confessing an error or offering an apology, it makes a reproof less offensive by making it less personal. One reason for the great popularity that proverbs enjoy among the Moors is their desire to be polite; thus a proverb is often an excellent substitute for a direct refusal, which might seem inappropriate or rude. It also stops a quarrel and makes those who were cursing each other a moment before shake hands and smile. And it is used as a kind of *'ar*, implying a conditional curse, to compel a person who has suffered an insult to forgive the offender. Proverbs are thus conducive to goodwill and peace.

If proverbs are to be studied from the points of view I have advocated—without any desire to prejudice other methods of study—it is, of course, necessary to know their intrinsic meaning, and this imposes upon the collector a task which has seldom been satisfactorily accomplished. Many proverbs are no doubt perfectly intelligible without an explanation; others are only apparently so, because they easily suggest an interpretation which is not the correct one; and others cannot even deceive us, because they defy any attempt to unriddle their occult meaning. I cannot, therefore, strongly enough insist on the necessity of recording the situations in which proverbs are used, unless the collector has made sure that they have no other meaning but that which they directly express. I was glad to find that Dr. Raymond Firth has likewise emphasised the duty of field-anthropologists to examine and record the attendant circumstances of proverbs in his suggestive articles on 'Proverbs in Native Life, with particular reference to those of the Maori,' published in two recent numbers of 'Folk-Lore.'

When we are sure of the intrinsic meaning of proverbs, and only then, we can find a reasonable solution of a problem that has proved a constant stumbling-block to collectors and compilers, namely, their classification. If proverbs are to be treated as a source of information for the sociological or psychological study of a people they cannot, as has usually been the case, be arranged simply in alphabetical order by the first letters of the first word. They must be grouped according to the subjects or situations on which they have a bearing, and be accompanied with all explanations necessary for the right understanding of their import and implications. Proverbs that are applicable in different situations may have to be repeated under different headings; but to judge by my own experience such repetitions need not be very many.

If due attention is bestowed upon the collection of proverbs, we may hope that the scientific study of them will better than hitherto keep pace with the progress made within other branches of folk-lore.

EVENING DISCOURSE.

THE MYSTERY OF LIFE.

By Prof. F. G. Donnan, F.R.S.

During the last forty years the sciences of physics and chemistry have made tremendous strides. The physico-chemical world has been analysed into three components—electrons, protons and the electro-magnetic field with its streams of radiant energy. Concurrently with these advances astronomy has progressed to an extent undreamed of forty years ago. The distances, sizes, masses, temperatures, and even the constitutions of far-distant stars have been ascertained and compared. The evolution of the almost inconceivably distant nebulæ and their condensation into stars and star clusters have been unravelled with a skill and knowledge that would have been deemed superhuman a hundred years ago. Amidst the vast cosmos thus disclosed to the mind of man, our sun winds its modest way, an unimportant star, old in years and approaching death. Once upon a time, so the astronomers tell us, its surface was rippled by the gravitational pull of a passing star, and the ripples becoming waves, broke and splashed off. Some drops of this glowing spray, held by the sun's attraction in revolving orbits, cooled down and became the planets of our solar system. Our own planet, the earth, gradually acquired a solid crust. Then the water vapour in its atmosphere began to condense, and produced oceans, lakes and rivers as the temperature sank. It is probably at least a thousand million years since the earth acquired a solid crust of rock. During that period living beings, plants and animals, have appeared, and, as the story of the rocks tells us, have developed by degrees from small and lowly ancestors. The last product of this development is the mind of man. What a strange story! On the cool surface of this little planet, warmed by the rays of a declining star, stands the small company of life. One with the green meadows and the flowers, the birds and the fishes and the beasts, man with all his kith and kin counts for but an infinitesimal fraction of the surface of the earth, and yet it is the mind of man that has penetrated the cosmos and discovered the distant stars and nebulæ. Truly we may say that life is the great mystery and the study of life the greatest study of all. The understanding of the phenomena of life will surely be the crowning glory of science, towards which all our present chemical and physical knowledge forms but the preliminary steps.

Observing the apparent freedom, spontaneity and indeed waywardness of many forms of life, we are at first lost in amazement. Is this thing we call life some strange and magical intruder, some source of lawless and spontaneous action, some fallen angel from an unknown and inconceivable universe? That is indeed the question we have to examine, and we may begin our examination in a general way by inquiring whether living things are subject to the laws of energy that control the mass phenomena of the inanimate world. The first of these laws, known as the law of the Conservation of Energy, says that work or energy can only be produced at the expense of some other form, and that there are definite rates of equivalence or exchange between the appearing and disappearing forms of energy. In a closed system we can make up a balance sheet, and we find that the algebraic sum of the increases and decreases, allowing, of course, for the fixed rates of exchange, is zero. That was one of the great discoveries of the nineteenth century. The physiologists have found that living beings form no exception to this law. If we put a guinea-pig or a man into a nutrition calorimeter, measure the work and heat produced and the energy values of the food taken in and the materials given out, we find our balance sheet correct. The living being neither destroys nor creates energy. One part of the apparent freedom or spontaneity of which I spoke is gone. Energy-producing action must be paid for by energy consumed. The living being does not break the rules of exchange that govern the markets of the non-living and the dead. Another great discovery of the nineteenth century, the so-called Second Law of Thermo-

dynamics, restricts the direction of energy transformations. Thus a large tank of hot water at an even temperature will not be found to cool itself and the disappearing heat energy to appear as the kinetic energy of a revolving fly-wheel or as the increased potential energy of a raised mass of metal, no other changes of any sort having taken place. Such a transformation need not, however, in any way conflict with the Law of Conservation. Unco-ordinated energy in statistical equilibrium, *i.e.* of even potential, does not spontaneously transform itself into co-ordinated energy. Now it would be a discovery of tremendous importance if plants or animals were found to be exceptions to this rule. But, so far as is known, the facts of biology and physiology seem to show that living beings, just like inanimate things, conform to the Second Law. They do not live and act in an environment which is in perfect physical and chemical equilibrium. It is the non-equilibrium, the free or available energy of the environment which is the sole source of their life and activity. A steam engine moves and does work because the coal and oxygen are not in equilibrium, just as an animal lives and acts because its food and oxygen are not in equilibrium. As Bayliss has so finely put it, equilibrium is death. The chief source of life and activity on this planet arises from the fact that the cool surface of the earth is constantly bathed in a flood of high temperature light. If radiation in thermal equilibrium with the average temperature of the earth's crust were the only radiant energy present, practically all life as we know it would cease, for then the chlorophyll of the green plants would cease to assimilate carbonic acid and convert it into sugar and starch. The photo-chemical assimilation of the green plant is a fact of supreme importance in the economy of life. This transformation of carbonic acid and water into starch and oxygen represents an increase of free energy, since the starch and oxygen tend naturally to react together and give carbonic acid and water. Such an increase in free energy would be impossible if there existed no compensating running-down or degradation of energy. But this running-down or fall in potential is provided by the difference in temperature between the surface of the sun and the surface of the earth, a difference of some five or six thousand degrees. All living things live and act by utilising some form of non-equilibrium or free energy in their environment. The living cell acts as an energy transformer, running some of the free energy of its environment down to a lower level of potential and simultaneously building some up to a higher level of potential. The nitrifying bacteria investigated by Winogradsky and recently by Meyerhof utilise the free energy of ammonia plus oxygen. By burning the ammonia to nitrous or nitric acid they are enabled to assimilate carbonic acid and convert it into sugar or protein. Other bacteria utilise the free energy of sulphuretted hydrogen plus oxygen. Fungi and anærobic bacteria utilise the free energy available when complex organic compounds pass into simpler chemical compounds. The close study of these energy exchanges and transformations is becoming a very important branch of cellular physiology, and in the hands of Warburg and Meyerhof in Germany and of A. V. Hill in England—to mention only a few eminent names—has already yielded results of the greatest value and importance. It would be a great thing if one of these investigators were to find a case where the Second Law of Thermodynamics broke down. Up to the present, however, it appears that all these energy transformations of the living cell conform with the Second Law as it applies to the inanimate world. Thus another part of the apparent freedom or spontaneity of life, of which I spoke before, disappears. A living being is not a magical source of free energy or spontaneous action. Its life and activity are ruled and controlled by the amount and nature of the free energy, the physical or chemical non-equilibrium, in its immediate environment, and it lives and acts by virtue of this. The cells of a human brain continue to act because the blood stream brings to them chemical free energy in the form of sugar and oxygen. Stop the stream for a second and consciousness vanishes. Without that sugar and oxygen there could be no thought, no sweet sonnets of a Shakespeare, no joy and no sorrow.

To say, however, that the tide of life ebbs and flows within the limits fixed by the laws of energy, and that living beings are in this respect no higher and no lower than the dead things around us is not to resolve the mystery. Consider for a moment a few of the phenomena exhibited by living things. The fertilisation of the ovum, the growth of the embryo, the growth of the complete individual, the harmonious organisation of the individual, the phenomena of inheritance, of memory, of adaptation, of evolution. Viewing these phenomena in the light of the facts known to physics and chemistry, it is little wonder that some modern philosophers have followed in the steps of certain older ones and

seen in the phenomena of life the operation of some strange and unknown vital force, some 'entelechy,' some expanding vital impulse; or at least some new and undiscovered form of 'biotic' or 'nervous' energy. It is difficult to resist the comparison of the developing embryo with the building of a house to the plans of an invisible architect. Growth and development seem to proceed on a definite plan and apparently purposeful adaptation confronts us at many stages of life. How can the differential equations of physics or the laws of physical chemistry attempt to explain or describe such strange and apparently marvellous phenomena? The answer to this question was given more than fifty years ago by the great French physiologist, Claude Bernard. We must patiently proceed, he said, by the method of general physiology. This is the fundamental biological science towards which all others converge. Its method consists in determining *the elementary condition of the phenomena of life.* We must decompose or analyse the great mass phenomena of life into their elementary unit or constituent phenomena. That was the great answer given by Claude Bernard. It is worthy of a Newton or an Einstein. It sounded the clarion note of a new era of biological science. To-day general physiology in its application of physics, chemistry and physical chemistry to the operations of the living cell is the fundamental science of life. Patiently pursued and step by step it is unravelling the mystery. The late Prof. Bayliss was one of the greatest of the pioneer successors of Claude Bernard in England. Another of the greatest ones was Jacques Loeb in America, whose death we all so deeply deplore. Although it is always invidious to mention the names of living men, it is good to think that in England to-day we possess three of the greatest living exponents of general physiology, namely, Barcroft, Hill and Hopkins, whilst in America the great work of Jacques Loeb is carried on by distinguished men of the high calibre of Lawrence Henderson, Osterhout and van Slyke. In Germany we have such great names as Meyerhof, Warburg, Bechhold and Höber, to mention only a few. What are these men attempting? Just what Claude Bernard set out in his programme, namely, by a patient, exact and quantitative application of the facts and laws of physics and chemistry to the elementary phenomena of life, gradually to arrive at a synthesis and understanding of the whole. That was precisely how Newton was able to determine the motions of celestial objects, namely, by going back to the elementary or fundamental law of gravitation. Through fine analysis to synthesis is indeed the only true scientific method. I do not mean that general physiology in the pursuit of its studies will not discover many things as yet unknown to us. The future findings of this science might be as strange to the investigators of to-day as the relativity theory of Einstein and Minkowsky was to the physicists of a few years ago. What I do mean is that the future discoveries and explanations of general physiology will be continuous and homologous with the science of to-day. Should, indeed, a new form of energy, 'a vitalistic nervous energy,' be discovered, as predicted by the eminent Italian philosopher, Eugenio Rignano, it will be no twilight will-o'-the-wisp, no elusive entelechy or shadowy vital impulse, but an addition to our knowledge of a character permitting of exact measurement and of exact expression by means of mathematical equations.

To give you the barest outline of the progress made by General Physiology since the death of Claude Bernard fifty years ago (his statue, together with that of Marcellin Berthelot, stands in front of the Collège de France) would require at least a hundred lectures and the encyclopædic knowledge of a Bayliss. Permit me, however, to mention one or two examples, and those with all brevity. The chemistry and energy changes of muscle have been discovered recently by Meyerhof in Germany and by A. V. Hill and Hopkins in England. When the muscle tissue contracts and does work it derives the necessary free energy, not from oxidation, which is not quick enough, but from the rapid exothermic conversion of the carbohydrate glycogen into lactic acid. When the fatigued muscle recovers it recharges its store of free energy; that is to say, by oxidising or burning some of the carbohydrate, it reconverts the lactic acid into glycogen. Thus in the recovery stage we have the coupled reactions of exothermic oxidation and endothermic conversion of lactic acid into glycogen. Everything proceeds according to the laws of physics and chemistry. The story of the mode of action and recovery of the muscle cells forms one of the most fascinating chapters of general physiology. Here we see one of the elementary phenomena of life already to a great extent analysed and elucidated. How this would have rejoiced the heart of Claude Bernard! That is one of the examples which I wished to mention. Another is what I may call the blood equilibrium. The red blood cells are enclosed in a membrane which does not allow the hæmoglobin to escape, and only permits

the passage of inorganic anions, though water and oxygen can pass freely in and out. Between the red cells and the external blood plasma in which they are submerged there exists a whole series of delicate exchange equilibria, such as water or osmotic equilibrium, ion-distribution equilibria, etc. The entrance of oxygen, which combines with the hæmoglobin, converts it into a stronger acid and ejects carbonic acid from the bicarbonate ions within the cell. Any disturbance of one of these equilibria produces compensating changes in the others. The whole series of equilibria can be written down in a set of precise mathematical equations. Thus two of the most important elementary phenomena of many forms of life, namely, respiration and the exchanges of the red blood cells, have been analysed, subjected to exact measurement and described by exact mathematical equations. The laws of physics and chemistry have again been found to hold good. The beautiful story of this blood equilibrium we owe to the labour of many distinguished physiologists, but chiefly to Lawrence Henderson and van Slyke in America and to A. V. Hill and Barcroft in England. That is the second example I wished to mention. These two will suffice for my present purpose. What is the lesson to be drawn from them ? No less than that the elementary phenomena of life are *deterministic*, that is to say, that events compensate or succeed each other just as in the physico-chemical world of inanimate things, and that their compensations and successions can be exactly measured and expressed in the form of precise mathematical equations. Determinism exists just as much or, if you please, just as little, in the elementary phenomena of the living as in those of the non-living systems familiar to physics and chemistry. Claude Bernard maintained that this was so. To the imperishable lustre of his name be it said that fifty years of exact research have borne witness to the truth of his faith. Do not misunderstand me here. True science should have no dogmas. It would have been a wonderful and a fine thing if recent research in general physiology had led to a non-deterministic sequence of phenomena in the elementary condition of life. During the last fifteen years theoretical physics, which has been undergoing a period of unexampled and daring advance, has dropped many a hint of the existence of apparently non-deterministic systems. The audacious springs of the electron within the atom from one energy level to another have often appeared to be ruled by considerations of relative probability rather than by any exact determinism in the ordinary sense of this word. But we cannot as yet be sure of anything in modern theoretical physics. Just as we now hear little of the jumping frog of Calaveras County, so modern wave mechanics has overwhelmed the discontinuously jumping electron, and seems to offer more promise of determinism than did that uneasy ghost. Thus determinism in the rigorous sense of the term is no infallible dogma of science. It would not be surprising if it did not exist in the minute phenomena of the world, since the apparent determinism of events on a greater scale is often only the result of a very high degree of statistical probability. Be that as it may, the investigations of general physiology, so far pursued, indicate that the elementary phenomena of life are quite as fully deterministic as phenomena on a corresponding scale of magnitude in the inanimate physico-chemical world.

Let us now make the daring supposition that general physiology, following the lead of Claude Bernard, has eventually succeeded in quantitatively analysing every side and every aspect of the elementary condition of life. Would such a supposedly complete and quantitative analysis give us a synthesis of life ? That is one of the most fundamental and difficult questions of biological science. A living being is a dynamically organised individual, all the parts of which work harmoniously together for the well-being of the whole organism. The whole appears to us as something essentially greater than the sum total of its parts. This aspect of the living individual was fully recognised by Claude Bernard. It has been emphasised recently by General Smuts in his remarkable book on Holism and Evolution. Life, as seen by General Smuts, is constantly engaged in developing wholes, that is to say, organised individualities. We may indeed learn how the regulative and integrating action of the nervous system, so beautifully and thoroughly investigated by that great physiologist, Sir Charles Sherrington, serves to organise and unite together in a harmonious whole the varied activities of a complex multicellular animal. We may learn, too, how those chemical substances, the hormones, discovered by Bayliss and Starling, are secreted by the ductless glands and, circulating in the *milieu intérieur* of an animal, act as powerful means for harmoniously regulating and controlling the growth and other activities of the various organs and tissues. Nevertheless, in spite of these great discoveries, the harmonious and dynamic correla-

tion of the various organs and tissues of a living organism ever confronts us as one of the great mysteries of life. In an inanimate physico-chemical system we think, if we know the situations, modes of action and interrelations of the component parts, whether particles or waves (or both), together with the boundary conditions of the system, that we have effected a complete synthesis of the whole. Though very crudely expressed, some such view as that lies at the basis of the Newtonian philosophy which rules our thought in the inanimate physico-chemical world. Is the organised dynamical unity of a living organism something fundamentally new and different? Confronted by a problem of this order of difficulty, it behoves us to be patient and to await the future progress of scientific research. Perhaps if we could actually witness and follow out the varied motions and activities of a single complex chemical molecule in a reacting medium we might find something not so very different from life. Or perhaps the organic unity of a living organism requires for its understanding some such explosion of human thought and inspiration as that which occurred when Einstein and Minkowsky discovered the true relations of what we call space and time. We may, however, be sure of this. The understanding, when it comes, will consist in something that permits of exact measurement and of precise expression in mathematical form, even though for the latter purpose a new form of mathematics may have to be invented.

Leibnitz once remarked that 'the machines of nature, that is to say, living bodies, are still machines in their smallest parts *ad infinitum.*' Anatomy and histology have progressively disclosed the structure of living things. Histology has revealed to us the cell with its nucleus and cytoplasm as the apparently fundamental unit of all the organs and tissues of a living being. What is contained within the membrane of a living cell? Here we approach the inner citadel of the mystery of life. If we can analyse and understand this, the first great problem—perhaps the only real problem—of general physiology will have been solved. The study of the nature and behaviour of the living cell and of unicellular organisms is the true task of biology to-day.

The living cell contains a system known as protoplasm, though as yet no one can define what protoplasm is. One of the fundamental components of this system is the class of chemical substances known as proteins, and each type of cell in each species of organism contains one or more proteins which are peculiar to it. Important components of the protoplasmic system are water and the chlorides, bicarbonates and phosphates of sodium, potassium and calcium. Other substances are also present, especially those mysterious bodies known as enzymes, which catalyse the various chemical actions occurring within the cell. Strange to say, the living cell contains within itself the seeds of death, namely those so-called autolytic enzymes, which are capable of hydrolysing and breaking down the protein components of the protoplasm. So long, however, as the cell continues to live, these autolytic enzymes do not act. What a strange thing! The harpies of death sleep in every unit of our living bodies, but as long as life is there their wings are bound and their devouring mouths are closed.

This protoplasmic system exists in what is known as the colloid state. Roughly speaking, this means that it exists as a rather fluid sort of jelly. There is something extraordinarily significant in this colloid state of the protoplasmic system, though no one as yet can say what it really means. Recollecting the statement of Leibnitz, one may be sure that the protoplasmic system of the cell constitutes a wonderful sort of machine. There must exist some very curious inner structure where the protein molecules are marshalled and arrayed as long mobile chains or columns. The molecular army within the cell is ready for quick and organised action and is in a state, during life, of constant activity. Oxidation, assimilation and the rejection of waste products are always going on. The living cell is constantly exchanging energy and materials with its environment. The apparently stationary equilibrium is in reality a kinetic or dynamic equilibrium. But there is a great mystery here. Deprive your motor car of petrol or of oxygen and the engine stops. Yes, but it doesn't die, it does not begin at once to go to pieces. Deprive the living cell of oxygen or food and it dies and begins at once to go to pieces. The autolytic enzymes begin to hydrolyse and break down the dead protoplasm. Why is this? What is cellular death? The atoms and the molecules and ions are still there. Meyerhof has shown that the energy content of living protein is no greater than that of dead protein. Has some ghostly entelechy or vital impulse escaped unobserved? Now it is just here, at the very gate between life and death, that the English physiologist, A. V. Hill, is on the eve of a discovery of astounding importance, if indeed he has not already made it. It appears from his work on non-medullated nerve cells and on muscle

that the organised structure of these cells is a *chemo-dynamic* structure which requires oxygen, and therefore oxidation, to preserve it. The organisation, the molecular structure, is always tending to run down, to approach biochemical chaos and disorganisation. It requires constant oxidation to preserve the peculiar organisation or organised molecular structure of a living cell. The life machine is therefore totally unlike our ordinary mechanical machines. Its structure and organisation are not static. They are in reality dynamic equilibria, which depend on oxidation for their very existence. The living cell is like a battery which is constantly running down, and which requires constant oxidation to keep it charged. It is perhaps a little premature at the present moment to say how far these results will prove to be general. Personally, I believe that they are of great importance and generality, and that for the first time in the history of science we begin, perhaps as yet a little dimly, to understand the difference between life and death, and therefore the very meaning of life itself. Life is a dynamic molecular organisation kept going and preserved by oxygen and oxidation. Death is the natural irreversible breakdown of this structure, always present and only warded off by the structure-preserving action of oxidation.

The last great problem which I shall venture to consider in this brief sketch concerns the origin of life. It might indeed be argued with much justice that such considerations are so far beyond the present stage of science that they are entirely without value. That, I think, is a bad argument and a worse philosophy. But, in any case, a dealer in mysteries is entitled to carry on his dealings as far and as best he may.

There appear to be two schools of thought in speculations of this character. The late Prof. Arrhenius supported the theory or doctrine of *Panspermia*, according to which life is as old and as fundamental as inanimate matter. Its germs or spores are supposed on this view to be scattered through the universe and to have reached our planet quite accidentally. You will remember that Lord Kelvin suggested they were carried here on meteorites. But against this idea the objection has been urged that meteorites in passing through our atmosphere get exceedingly hot through friction with the air. Arrhenius brought forward the very ingenious idea that the motion in and distribution through space of these germs or spores were caused by the pressure of light, which in the case of very minute bodies can overcome the attraction of gravitation, as is often seen in the tails of comets. Many objections have been brought against this theory of Panspermia. It has been argued that either the cold of interstellar space or the ultra-violet light which pervades it would be sufficient to kill such living germ or spores. Certainly ultra-violet light is a very powerful germicide, though many spores can withstand very low temperatures for long periods of time. Perhaps the chief objection to this doctrine of Panspermia is that it is a hopeless one. Not only does it close the door to thought and research, but it introduces a permanent dualism into science and so prejudges an important philosophical issue.

If the living has arisen on this planet from what we regard as the non-living, then various extremely interesting points arise. It is already pretty certain that it originated, if at all, in the primeval ocean, since the inorganic salts present in the circulating fluids of animals correspond in nature and relative amounts to what we have good reason to believe was the composition of the ocean some hundred million years ago. The image of Aphrodite rising from the sea is therefore not without scientific justification. We have seen that life requires for its existence a certain amount of free energy or non-equilibrium in the environment. In the early atmosphere there was plenty of carbon dioxide, and probably also some oxygen, though nothing like so much as at present. Volcanic action would provide plenty of oxidisable substances, such, for example, as ammonia or sulphuretted hydrogen. As we have seen previously, certain bacteria could therefore, in all probability, have lived and assimilated carbon dioxide, producing organic substances such as sugar and proteins. This argument, though very interesting from the point of view of Panspermia, has a serious flaw in it from the present point of view, since the bodies of these bacteria would necessarily contain the complicated organic proteins of the protoplasm. When the earth cooled down to a temperature compatible with life, it is probable that the ocean contained little, if any, of such organic substances or their simpler organic components. There was likewise no chlorophyll present to achieve the photo-chemical assimilation of carbon dioxide. Hence the necessity of considering how organic substances could have arisen by degrees in a primeval ocean originally containing only inorganic constituents. The late Prof. Benjamin Moore took up this question and endeavoured to prove that colloidal iron oxide, in the presence of light, moisture and carbon dioxide, could produce formaldehyde, a substance from which sugar can be derived. This work o

Moore's has been actively taken up and developed by Prof. Baly in recent years. He has conclusively proved that, in the presence of light, moisture and carbon dioxide, formaldehyde and sugar can be produced at the surface of certain coloured inorganic compounds, such as nickel carbonate. We may therefore conclude that the production of the necessary organic substances in the primeval ocean offers no insuperable obstacle to science. But there is still a very great difficulty in the way, a difficulty that was pointed out by Prof. Japp, I think, at a former meeting of the British Association in Dover. The protein components of the protoplasmic system are optically active substances. As is well known, such optically active substances, *i.e.* those which rotate the plane of polarisation of polarised light, are molecularly asymmetric and always exist in two forms, a dextro-rotatory and a lævo-rotatory form. Both these forms possess equal energies, and so their formations in a chemical reaction are equally probable. As a matter of fact, chemical reaction always produces these two forms in equal quantities, and so the resulting mixture is optically inactive. How, then, did the optically active protein of the first protoplasm arise ? In spite of many attempts to employ plane or circularly polarised light for this purpose chemists have not, so far as I know, succeeded in producing an asymmetric synthesis, *i.e.* a production of the dextro- or lævo-rotatory form, starting from optically inactive, that is to say, symmetrical substances. The nut which Prof. Japp asked us to crack has turned out to be a very hard one, though there is little reason to doubt that it will be cracked sooner or later. Even were this accomplished, very formidable difficulties still remain, for we have to imagine the production of the dynamically organised and regulated structure of living protoplasm. Prof. Guye of Geneva has in recent years offered some very interesting considerations concerning this difficult problem. According to the statistical theory of probability, if we wait long enough, anything that is possible, no matter how improbable, will happen. All the ordinary events of life happen frequently because they are very probable, whilst the improbable things happen on an average relatively rarely. The celebrated problem of the ‘typewriting monkeys’ may be cited as an example. If six monkeys were set before six typewriters and allowed to hit the keys at their own sweet will, how long would it be before they produced—by mere chance—all the written books in the British Museum ? It would be a very long, but not an infinitely long, time.

Now the Second Law of Thermodynamics, to the scrutiny of which we subjected the phenomena of life, is purely a law of statistical probability. The odds against Mr. Home, the celebrated medium of former days, levitating without any compensating work or energy effect, are enormously heavy. The unco-ordinated energy in and around Mr. Home might indeed spontaneously convert a part of itself into the co-ordinated energy of Mr. Home rising majestically into the air, but the safe odds against that happening are simply terrific. The ordinary large-scale happenings of the world, with which we are so familiar, are simply events where the odds on are gigantically enormous. The coming down of Mr. Home with a bump is an event on which we could safely bet, with an assurance of success quite unknown in racing or roulette. The theory of probability tells us that there always exist fluctuations from the most probable event. In the physico-chemical world of atoms, molecules and waves these fluctuations are ordinarily imperceptible, owing to the enormous number of individuals concerned. In very small regions of space, however, these fluctuations become important, and the Second Law of Thermodynamics ceases to run. We have seen that the structure of living protoplasm is extraordinarily fine and delicate. Do events happen here which are to be classed as molecular fluctuations, or even as individual molecular events, rather than as the mass-probabilities which have led men to formulate the Second Law ? Something of that sort was probably in the mind of Helmholtz when he doubted the application of this law to the phenomena of life, owing to the fineness of the structures involved. The reasoning of Guye bears rather on the origin of life. Is the spontaneous birth of a minute living organism, he asks, simply a very rare event, an exceedingly improbable fluctuation from the average ? This is a fascinating point of view, but it possesses one drawback. What is there to stabilise and fix this rare event when it occurs ? Guye has himself realised this difficulty, but it may not be an insurmountable one. Such rare fluctuations may occasionally cause matter and energy to arrive at peculiar critical states where and whence the curve of happening, the world space-time line, starts out on a different path, and a new adventure arises in the hidden micro-cosmos.

If life has sprung from the non-living, its earliest forms must have been (or must be?) excessively minute. We must look for these, if anywhere, in those queer things

that the bacteriologists call the 'filterable viruses.' These are living bacteria so exceedingly small that not only are they invisible in the finest microscopes, but they pass easily through the minute pores of a Chamberland porcelain filter. D'Herelle has recently discovered the occurrence in certain bacterial cultures of what he calls the 'bacteriophage.' These seem to be excessively minute organisms which can hydrolyse certain ordinary bacteria. They constitute an extremely fine and filterable 'virus.' Quite recently Bechhold and Villa, in the Institute for Colloid Research at Frankfurt, have devised a new and ingenious method whereby these minute organisms can be rendered visible and measured. The process consists in depositing gold on them, strengthening up these gilded individuals as one enlarges the silver particles in an insufficiently exposed negative, and obtaining as end result a sort of metallic skeleton of the original organism. It appears that the individuals of D'Herelle's bacteriophage are small discs whose diameter lies between 35 $\mu\mu$. and 100 $\mu\mu$. Now the diameter of an ordinary chemical molecular is of the order of 1 $\mu\mu$., *i.e.* one-millionth of a millimetre. Colloid particles are much bigger than that. If it be proved beyond all doubt that they are really living organisms, then the individuals of D'Herelle's bacteriophage are comparable in size with known colloid aggregates of non-living matter. This result gives rise to strange hopes. If we can find a complete continuity of dimensions between the living and the non-living, is there really any point where we can say that here is life and there is no life ? That would be a daring and perhaps a dangerous theme to dwell on at the present time. But where there is hope there is a possibility of research. And who will set a limit to the discoveries that are possible to science in the future ?

I hope no reader of this meagre sketch of mine will call me a materialist or a mecanist. All I have endeavoured to show, however briefly and inadequately, is that the sincere and honest men who are advancing science, whether in the region of life or death, are those who measure accurately, reason logically, and express the results of their measurements in precise mathematical form. A hundred or a thousand years from now mathematics may have developed far beyond the extremest point of our present-day concepts. The technique of experimental science at that future date may be something undreamed of at the present time. But the advance will be continuous, conformal, and homologous with the thought and reasoning of to-day. The mystery of life will still remain. The facts and theories of science are more mysterious at the present time than they were in the days of Aristotle. Science, truly understood, is not the death, but the birth, of mystery, awe and reverence.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

The Conference was devoted to the subject of scenic beauty and its preservation.

The first session, September 6, dealt with the scenic amenity of town and country in the United Kingdom, and a resolution was proposed and carried which subsequently received the endorsement of the General Committee of the Association and was referred to the Council for action.

The second, and concluding, session, September 11, dealt with the scenery of the English Lake District and its preservation.

Session of September 6th.

THE PRESERVATION OF SCENIC BEAUTY IN TOWN AND COUNTRY.

ADDRESS BY

VAUGHAN CORNISH, D.Sc.,

PRESIDENT OF THE CONFERENCE.

1. Great Britain's heritage of Scenic Beauty.

This introductory address on the Preservation of Scenic Beauty in Town and Country leads up to a resolution which will be proposed by the delegate of a society situate in Scotland and seconded by the delegate of one situate in Northern England. The types of scenery on which I shall draw for illustration will therefore be selected mainly from the Southern and Midland Counties of England and from Wales, adjacent on the West.

Scenery, the outdoor view, is the aspect of the world which all men have in common. Its true beauties, the aspects more than pleasing which fill the mind with joy, result from combinations which produce mutual enhancement of the parts, harmonies in the full sense of the word.

The scenery of a country is artificially modified from generation to generation, and it is necessary therefore that we of the academic world should discover and define the combinations which result in scenic beauty if we are to take the responsibility of advising on measures for its preservation. We have, in fact, to lay sure foundations for an æsthetic of scenery.

Great Britain's heritage in scenery is of town and suburb, village and farm, wild waste places, and the splendid setting of the sea, all under the canopy of soft skies given by oceanic climate.

2. Scenic Harmonies of the Town.

The characteristic beauty of the street is the effect of a vista, the pleasant path by which the eye follows converging lines to a point of rest in the far distance. Piecemeal reconstruction of streets is necessary in a progressive era, and, in order to preserve the dignity of the street, uniformity

of cornice lines must be enforced by municipal authority; otherwise the vista vanishes, camouflaged by vertical strips.

The necessary increase in height of houses is reasonably lamented when disproportionate to width of thoroughfare, but the erection of lines of lofty buildings facing great open spaces is free from this drawback. The beginning of the epoch of steel-framed sky-scrapers has, it is true, the inevitable disadvantage of rearing isolated blocks which cut the sky harshly with square quoins, but as the type of building becomes more general these blocks unite in a long façade more imposing than any vertical plane in scenery except the cliff which rises sheer from the waters of the ocean.

Hearing that lofty steel-frame building had begun in Park Lane, I went to see the effect. In Victorian days I spent so many pleasant and idle hours on the shady lawns of Hyde Park between the Achilles statue and Grosvenor Gate that I grew fond of the irregular line of miscellaneous architecture seen through the plane trees and beyond the border of brilliant flowers. The new building dwarfs them all, and by breaking a pattern blurs the pleasant memories woven into a view of which the pattern was a part. But this drawback was compensated by a new element of nobility in the scene, that of imposing loftiness, which was most felt when the new building was viewed through the bare boughs of the plane trees. I found also another improvement, for when looking across the open Park with its spacious sky the presence of a lofty façade gave what was wanted to complete an opulent impression of general amplitude. I returned to the spot a few months later when the lattice of the boughs was improved by the perforated screen of half-opened leaves, and the satisfactory impression of the first visit was not only confirmed but strengthened. Yet what is happening makes many people shudder and prompts gloomy comment on the commercialism of the age. If Park Lane were destined to remain as it is at the present moment I would not undertake to say that the break in the pattern was pictorially justified, but I am visualising the pattern as it will be when complete. Hyde Park will then be glorified by a long and lofty façade,[1] as a spacious plain is more glorious if bounded by a range of mountains than a line of hills. Meanwhile the individual buildings will gain in the details of their structure as the artists gain greater mastery of the new medium.

In most great cities there are lofty outlook stations accessible only with much labour, as at the Monument and St. Paul's in London. In Edinburgh and elsewhere an Outlook Tower has been built through the prescience of Mr. Patrick Geddes. In the lifts which are necessarily installed in lofty steel-frame buildings, municipalities have ready to their hand a means of providing the public with easy access to outlook points selected for the beauty of their prospect.

The city skyline of spire and pinnacle is never more imposing than in misty air, which emphasises outline as much as it diminishes relief, and the ruddy tinge of sunshine struggling through a pall of smoke confers excitement of colour which counteracts the dulling effect of lessened light. But in our climate there will never be lack of misty days, and, even apart from

[1] The assumption is made that the local authority will insist upon a sufficient measure of uniformity to secure this result.

considerations of health, we pay too dearly for the fine, lurid effect of smoke. The black coat on buildings obscures the shadowing to which cornice and colonnade owe much of their beauty. The growth of vegetation is so checked as greatly to impair the contribution of blossom, foliage and tracery of boughs which is desirable not only for its own beauty but as a foil to the insistent forms of architecture, multiplied in cities beyond the endurance and capacity of the eye. The effect of smoke is equally adverse to the social scenery of our cities, for, by screening the warmth, the brightness and the vitalising rays of the sun, inducing fog and smirching every garment of fine texture and bright colour, it militates against the habit of *al fresco* meals and social intercourse out of doors during hours of rest which adds so much to the scenery of cities in warm and sunny lands. When the pall of smoke is removed it will be found that the paving and surface draining of towns has lessened the drawback of our natural climate for sedentary outdoor recreation, which is mainly that of exhalation from damp ground. Moreover, the better growth of vegetation will bring something of country fragrance to the air of towns, the fragrance which has so strong an influence upon our æsthetic mood and power of appreciating beauty.

The preservation of scenic harmony is never more difficult than where new construction has to be undertaken among venerable buildings. Yet such problems can be solved, as I learnt when I lately went to Winchester to revive the memory of ancient beauties which I had not seen for thirty years. It was a perfect day in early spring, and Cathedral Close and College Precinct were seen in all their mellow charm. Noticing a new building in College Meads I turned aside and found myself within a cloister erected as the war memorial of Wykhamists. Here I felt the spirit of the past and saw an added glory to Winchester. There was neither lifeless imitation of traditional forms nor architecture so alien as to introduce incongruity. The roof of rough stone, suited to its exposure and pleasantly breaking up the sunlight, the good smooth stone and reposeful circle of the arches, the splendid message of the inscription to the dead which circles the knapped-flint walls of the cloister in letters of white stone shaped to the old Lombard script, are the satisfying outcome of that co-operation between an artist and a scholar which should always be sought for construction in such sites. Moreover, the hand of the careful craftsman can be seen, the final satisfaction of the nearer view of architecture.

3. Scenic Harmonies of Suburbs and Seaside Resorts.

Ever since our towns grew large, the city man longing for the sweet fresh air of the fields and the scenery of vegetation has sought a home in the situation bordering both the country and the town, but no sooner was he settled than the locus of these advantages shifted further out. By fixing a rural ring round the city and building compact suburbs beyond, the selection of a home permanently suitable for the average business man would be made possible for the first time since the beginning of the industrial epoch.

The present suburbs are often pre-eminent in garden decoration, especially in the tree blossom and flowering shrubs displayed to the road,

but the scenery of social life is impoverished by radial building. The straggling suburb is inferior to the town in illustration of collective life and inferior to the country in illustration of the round of individual occupation. The detached suburb of compact plan, by providing better illustration of both individual and collective occupation, would remove the common reproach that suburban scenery is uninteresting. Moreover we can plan its residential roads so as to combine excellencies which in Great Britain have hitherto been separately associated with the college, the mansion, the cottage and the villa. The plan to which I refer is well established on the other side of the Atlantic, where the admirable example of Toronto is fresh in the minds of many members of the British Association. The front gardens are not fenced from one another, and in consequence the detached villas stand in the dignified sociability of collegiate architecture. The avenue of shady trees by which the citizen goes forth to his work in the morning and returns at eventide is stately as the approach to a lordly country mansion. The front gardens with their flowers for all to see have the friendly brightness which is the charm of the English cottage garden open to the road, whilst the gardens at the back of the houses, adequately fenced from one another, give the privacy which is a cherished character of English villadom.

The large parks and heath lands now being re-planned, sometimes with a central golf course, are free both from the bane of nineteenth-century building and from the pressure to conform to an earlier tradition. Here adaptations of a Mediterranean type of architecture, harmonising with the landscape, are already to be seen. These embody the upper loggia and other facilities for shelter combined with open-air life. It cannot be too clearly realised that this return to Nature is an advance upon any of the earlier architecture of England.

The sea coast is our chief health resort, both for the annual holiday from business and for the restful years of retirement, and sometimes a suburb also for the city man. Half smothered in the modern growth of the seaside resort are the cottages of the old fishing village which was rightly placed to hug the shore. Here and there on our coast can still be found an untouched fishing village in a cove beneath the protecting cliff which preserves an unspoilt scene of the adaptation of occupation to environment. The general practice of developing the seaside resort on similar lines, with building front close to the beach, is however radically wrong. The building-line should be placed at the back of a broad lea, for a mere roadway and footpath between the houses and the beach is utterly inadequate as seaside pleasaunce for a considerable town, and the mind can with difficulty receive the message of the free and open ocean amidst a jostling crowd. Fortunately, the more spacious planning is a counsel of economy as well as amenity, for the need for erecting costly sea defences is postponed, and meanwhile the growing population becomes better able to bear the financial burden.

4. Scenic Harmonies of Farm and Village.

The country parishes of the English lowland have a decorative character unsurpassed in quiet charm. The land undulates, rivers flow quietly in gracious curves, there is wealth of broad-leaved trees of rounded

form, and the fields are divided by bushy hedges where the natural vegetation is preserved. The preference displayed by cultured Englishmen during the eighteenth century for the scenery of prosperous agriculture was due in part to a shrinking from sterner aspects, but we have only to imagine the countryside as it was on the eve of nineteenth-century building (hurried, haphazard and largely in staring brick and poor slate) to realise that rural England of the eighteenth century would have held us enchanted by the perfection of its repose. House building since the great war has been even more rapid than in the nineteenth century. It is, as Sir John Russell remarked at a meeting of this Conference, of a curiously mixed kind. The best houses are excellent in form, tone and colour, and take their place in the landscape more quietly than the late-Victorian villa. The worst hold the eye against its will by harsh form and staring colour, and, in many cases, by the conspicuousness of a site chosen for the sake of a wide prospect. While deploring such philistinism let us not forget that the Englishman's fondness for trees and love of privacy will largely remedy the present state of things. Experience tells us that in twenty years the new villa will be almost hidden in a grove, even though the view from the windows be partly screened.

In the great avenues of a well-planned city we have the stately effect of the vista, in many English hamlets and village streets the subtle charm of grouping which conforms spontaneously to the winding course of the valley's water-way, as beneath the Berkshire downs, on the Cotswolds and in the coombs of Devon. The preservation of this picturesque inheritance is fortunately made easier by the revenue derived from the motor industry which provides funds for the by-pass required for acceleration of traffic.

The winding country lane with over-arching trees has long been a cherished possession of English scenery, in summer a corridor of cool green shade, in autumn an avenue of golden light, but we have never had Napoleonic roads bordered by league-long avenues and, as Professor Patrick Abercrombie has pointed out, the requirements of motor traffic provide the occasion for introducing this new element of beauty.

In the eighteenth century the traveller crossing England passed through a string of villages and large and small towns. Railways were, however, laid out so as to avoid villages and many of the smaller towns, so that the traveller of the nineteenth century rolled peacefully through mile after mile of verdant fields. The motorist of the twentieth century returning to the main roads receives a very different impression of the countryside, and consequently overestimates the recent encroachment on rural England.

If we leave the main motoring roads and also reject the cheapened charms of certain spectacular features of scenery, we find large blocks of agricultural England in which scenery is unaffected by recent occurrences. I lately visited a line of twelve country parishes lying on the slope of the West Berkshire downs overlooking the Vale of White Horse, places which I knew intimately five-and-thirty years ago and had not seen since. There was no perceptible change in the lay-out of the fields, in the operations of agriculture, or in the architectural appearance of the villages. The light car had replaced the dog-cart upon the roads, otherwise all objects were as a generation since. One attribute of rusticity was, however, impaired, that of seclusion ; the price paid for the rapidity and ease of access by car.

I have also gone back, after the lapse of more than forty years, to the village of Debenham in East Suffolk, where I was born and bred. Windmills have fallen into disuse and fewer handicrafts are carried on in the village street, but, throughout the thirteen-mile drive from the railway station, architecture and agriculture presented the same appearance as of old, even to the distinctive chestnut colour of the cart horses and the manner of their harnessing to the plough. Visiting the school at Debenham, I found no apparent change of type. The true-blue eyes characteristic of the East Anglian stock preponderated as much as among the children of two generations back whom I knew in my boyish days. As I watched the school disperse, I felt that the charm of the high street was due as much to the blithe movement of happy children as to the statical background of old gabled houses.

5. The Needful Background of Wild Nature.

Urban and agricultural scenery, though utterly unlike in decorative character, have the common element of human effort and contrivance. The scenery of wild nature from which this element is absent is not always more decorative than that of cultivated land. The landscape which is, perhaps, most satisfying for residence is that in which civilisation is seen with ample background of the wild. But in many English counties there is no such background, for cultivation covers hill and dale. Therefore, as we cannot everywhere view the wild, it is the more important to preserve such complete landscapes of untouched Nature as we still possess, refuges where we can steep ourselves in the aspect of spontaneity with no reminder of Man or his works. Nature and Mankind are twin sources of inspiration, but the intimate and moving scenes of human life are not for the most part comprised in the outdoor view and do not therefore form part of the scenery of farm and city. Nature on the other hand, though many of its wonders are microscopic, is most inspiring in the general view, and it is necessary for full development of the personality of a nation that the scenery accessible to the people should comprise the untouched elemental prospects which are unrivalled in their power to impart a sense of the Infinite.

Of all the greater manufacturing countries with dense population, none equals our own in accessibility of coast and proportion of coast line to area. The sea shore provides a purely elemental prospect, the panorama of sea and sky with its unmatched horizon and never-failing harmony of tone and colour. The cliff by the sea presents from its precipitous verge an outlook unsurpassed even by Alpine scenery. Here from our island home we gaze upon a scene untouched by time, an image of infinity and eternity unequalled in its potential influence upon the loftier imaginings of our people. But although the view from the cliff cannot be impaired, access to the view is often denied, and I submit that the time has come when no new enclosure extending to the cliff should be permitted and no further restriction of access allowed.

6. Education in Scenery.

It is the duty of the academic world to educate the nation in the appreciation of its heritage of scenery. When the benefits of scenic

beauty are thus extended from the few to the many, the people themselves will guard the goodly heritage. The best method for carrying out this instruction in school is in connection with regional survey. The scenery of the home region has a more than local character, for it is almost an epitome of the scenery of the world, comprising the round of day and night, the response of vegetation to the seasons, forms of cloud common to all countries, the rising and setting of the sun and the revolution of the changeless constellations. Moreover, scenery appeals to the mind as a whole, for everything that we know about an object affects the way in which it appears to the eye, yet the feeling imparted by appearance is not limited by the bounds of knowledge. If the teacher will concentrate upon the perfection of characterisation which brings the understanding of the heart, response among pupils will be widespread, for the æsthetic faculty is latent in the generality, not, as the creative power of artistry, an exceptional endowment. Neither do the cares of poverty prevent the mind from dwelling on scenic beauty, as all who have travelled in Japan are well aware. There the coolie, whose standard of living is far below that of our working class, goes on pilgrimage to see each culminating beauty of the seasons, for the birthday of a favourite flower is a religious festival throughout the land. At the back of this are centuries of education in æsthetic perception.

Those of us who aspire to be instructors in scenic beauty must submit to a certain discipline in order to acquire mastery of the subject. In our walks abroad we must let busy thought quiet down, that the mood of receptive attention may have full play. Then the whole being can be stirred, for the emotions aroused by scenic harmonies are far from being merely primitive; they result not only from inheritance but from the sum of all the past feeling, thought and action of a man's own life. It is only the jostling, obtrusive thought of the hour which is eliminated in the contemplative mood. To all who attain this receptive habit, the harmonies of scenery bring an integration of the personality which is beyond the reach of those who neglect the correlation and synthesis of thought and feeling.

7. The Necessity of Measures for Protecting Scenery.

Our special function in regard to preservation of scenic beauty is research and education, but both processes require time, and the enemy, ugliness, must be held by a frontal force while we get round the flank. It is universally admitted that there are parts of the country where irreparable damage to scenery is needlessly threatened,[2] and it therefore appears desirable that the British Association for the Advancement of Science should urge His Majesty's Government to stimulate the employment by local authorities of the powers already conferred upon them by Parliament for the preservation of scenic amenity in town and country.

A resolution to this effect will be proposed and seconded by the next speakers.

[2] It may be well to warn enthusiasts of forestry that if the culminating heights of Down and Moor be planted with trees their beauty as distant sky-line will be completely ruined.

Dr. Charles R. Gibson (delegate of the Royal Philosophical Society of Glasgow), in proposing the resolution introduced in the Presidential Address, drew a few illustrations from Scotland, dealing specially with the works at Ben Nevis, and pointed out that, in such cases, the difficulty of the preservation of scenic beauty was in some measure one of pounds, shillings and pence. If it cost no more to build garden cities than the style of workmen's houses adopted, the engineer would be more willing to consider the preservation of scenic amenity. It was, therefore, necessary to employ persuasion, if not compulsion, to attain the object which the conference have in view.

Another point dealt with was the new road from Tyndrum to Balachulish through Glencoe. He referred to the letter from the Association for the Preservation of Rural Scotland sent to the Minister of Transport, the result of which was a reconsideration of the plans in the light of the criticisms offered.

Credit was due to the oil companies for the withdrawal of petrol advertisements from the country roads. It was suggested that the desire for economy was not such an important factor in the case of towns, in which the chief difficulty was that extensions to, and alterations in, existing things had to be made at different dates, producing a patchwork effect; a town could not be planned at one time as can a garden city.

Pointing out that industrial Glasgow could not hope to vie in scenic beauty with historic Edinburgh, Dr. Gibson said it was interesting to note some new light on William Morris' opinion of Glasgow. It had been disappointing to read, in the introduction to his collected works, that Glasgow met with his unqualified disapproval, and that the one admitted excellence of the city was the fine arrangements for getting away from it. In a recent article Lewis Spence said that he had been told by Pittendrigh Macgilvary, who was with Morris on his visit to Glasgow in the seventies, that the mediævalist was so enchanted and bewildered by the city that he went into rhapsodies.

It was stated that Glasgow now possessed 1,894 acres of public parks within the city boundaries, and following up the President's remarks on outlook stations, Dr. Gibson suggested that Glasgow should have a camera obscura in one of the towers of the Art Galleries, in which the scenic beauty of the surrounding district might be viewed. He thought it a great pity that the use of these historic instruments should be allowed to die out.

Mr. T. Sheppard, vice-chairman of the Corresponding Societies' Committee, in seconding the resolution said that in his dual capacity as the representative of the Yorkshire Naturalists' Union, and of the Museums Association, he was proud to have the opportunity of thanking Dr. Vaughan Cornish for his interesting address. Both societies he represented had the scheme voiced by Dr. Cornish well at heart.

The Yorkshire Naturalists' Union, one of the oldest of its kind in the country, with about 4,000 members and associates, had for many years taken an active part in the preservation of natural monuments and of the fauna and flora of the county. Many of its members privately subscribed to a fund to pay watchers to look after the rare birds nesting on the Spurn Peninsula, at Hornsea Mere, the Bempton Cliffs, and in the dales bordering the Lake District. In these areas many exceedingly rare species were still, thanks to the Union, able to exist and bring forth their young. In addition to its members, there were about forty affiliated natural history and scientific societies in the county, each of which took an active part in endeavouring to preserve the natural features, to prevent the extermination of rare plants and animals, in looking after the commons, footpaths, and so on. The Union's journal, 'The Naturalist,' had also assisted. The encroachment of buildings on natural features was discouraged.

The Museums Association consisted of representatives from the various National and Provincial Museums in Great Britain, and the directors of the museums and committees had largely contributed towards the end suggested.

To-day an enormous number of valuable and historic buildings and parks were preserved for the benefit of the public for all time by corporations and private bodies, who had turned them into museums and open spaces of one description or another. In some instances the buildings were preserved for their purely architectural features, in others for their associations with important people who were connected with them. It was impossible to enumerate them all or refer to the great number of places which were under the control of museum authorities, but one might mention two or three which came to one's mind, merely as types.

In Yorkshire they had the Bolling Hall at Bradford, Wilberforce Museum at Hull, the Brontë Museum at Haworth, the Folklore Museum in the Tithe Barn at Easington, and others. There were also the Hallith Wood Museum at Bolton, Strangers' Hall at

Norwich, and innumerable others which contained objects connected with the lives of the people formerly associated with the building, the latest acquisition, of course, being Darwin's house at Down. In many cases land, timber, and other features were also preserved. Particulars of other similar museums in the country would be found in the report of the Public Museums of the British Islands to the Carnegie Trustees by Sir Henry Miers, recently issued.

He gave these as examples of the way in which corporations and private individuals could assist in carrying out the work suggested by the Chairman.

The Earl of Crawford and Balcarres, President of the Council for the Preservation of Rural England and Honorary President of the Association for the Preservation of Rural Scotland, supporting the resolution, said that the matter of preserving rural scenery was really urgent. Progress in one direction and another, notably in transport facilities, had made it more and more easy for our landscape to be attacked and to be injured. The reason was that, wonderful as the beauty of our country was, it was of a character differing from those of foreign countries, where the scenery was on so large and grandiose a scale that the assaults of modern transport or bungalows were unable to do it harm.

During the last few months a number of large steel masts had been erected in East Fife for the purpose of overseas telephones. He was not opposed to that, but had the people responsible for them taken the trouble to consult the experts and thoughtful people who formed the Association for the Preservation of Rural Scenery in Scotland it would have been quite easy, without impairing the scientific efficiency of the system, to have shifted the masts from one point to another in such a way as to avoid injury to a very charming and beautiful bit of Scottish scenery. Those good fellows, however, either did not know or did not think it worth while to take the trouble to find out how least offensive those offensive things could be made. He thought that public opinion was gradually impressing itself upon the people responsible for many of those things, and as time went on they would find their rulers more amenable to criticism and less liable to make those gross mistakes.

He wished also that they could persuade the right authorities to take a little more trouble in the work they did in connection with thoroughfares. He could not help thinking that they were a little too ambitious in road schemes.

Their rural roads were being converted into county roads, county roads were being converted into great thoroughfares, and great thoroughfares were being converted into railways, and the wretched person who did not travel in an armoured car went about the country in fear of his life.

It was possible to improve our road system in such a way as to inflict no serious injury upon the surrounding country. He was glad to say that people were now interesting themselves in that subject, and a new society for the beautifying of roads had been started. He hoped that it would not be thought that they could mitigate the ugliness of a road by simply planting it with trees.

He would like to prevent the invasion of those extremely ugly bungalows. There was no reason why a bungalow should be ugly, and there again a little thought and a sense of congruity would indicate that wherever one put a new building, with trouble it could be made to conform less or more with the landscape, or at any rate objectionable features could be reduced, and with the flux of time and the growth of vegetation one could hope that it would take an honourable place in the landscape. It was lack of thought and knowledge and sympathy which produced those mistakes. Our municipal rulers, also, had determined to be artistic, and so the ground plans of those great new suburbs had been entirely constructed from a paper point of view and not at all from external or an 'eye-and-scenery' point of view. One could not see into those towns, when one was in them it was not possible to see out of them, and in no direction was it possible to see through them. The houses were at every possible angle, one could never see any vista in any direction, and the only thing which seemed to have been arranged was that each house should look into the back garden of its neighbour.

Public opinion was really awakened, but to be efficient it must be properly organised and strengthened. He hoped that all interested in the preservation of our national scenery would do their best by supporting those societies lately organised for that purpose.

Sir John Stirling-Maxwell, Bt., Vice-President of the Association for the Preservation of Rural Scotland, speaking in support of the resolution, referred to the terrible incubus of smoke. People who had not lived in an industrial neighbourhood,

he said, could not realise how depressing the effect of smoke was since for something like 300 days of the year the country was deprived of all its beauty.

Professor F. G. Baily, Edinburgh, who attended as delegate of the Association for the Preservation of Rural Scotland, referred to the water-power scheme operating in the Clyde valley, and said that there were very few waterfalls which were worth utilisation, and where a waterfall formed an essential part of one of the most beautiful areas near Glasgow it should be left alone. Before they could get local powers for the preservation of amenities they must show a strong popular demand, and they must therefore primarily set themselves to stir up popular demand and popular appreciation towards the importance and improvement or preservation of amenity. To that end he suggested the formation of local associations which would concentrate their activities in their own particular districts.

Miss R. M. Fleming, speaking for the Geographical Association, said that if children were to be taught how to live as well as how to earn a living, the appreciation of visual beauty must be included in the school curriculum. If the class-room and playground were kept so that the children's sense of beauty did not atrophy during the long school hours, the beauties of the world beyond would be apprehended when pointed out by the teacher. It was specially important that children in rural schools should have their eyes opened to the beauty of their surroundings in order that they might act as its future guardians. Many aspects of city life also had a beauty of their own which it only needed instruction to appreciate.

Mr. T. Wilfred Jackson (Manchester), representing the Conchological Society of Great Britain, spoke on the subject of preservation of the scenery of Dovedale.

Dr. E. H. Davison, of the Royal Geological Society of Cornwall, spoke on the urgent necessity of taking steps to prevent encroachment on right of access to the Coastguard path round the coast of Cornwall.

Dr. H. Hamshaw Thomas, Cambridge, announced that, as a result of a resolution passed at the conference of delegates last year, the Under-Secretary of State had called a conference to discuss the possibility of devising a more effective form of by-law for the preservation of wild plants in Britain. The following by-law had been approved at that conference :—No person shall (unless authorised by the owner or occupier, if any, or by law so to do) uproot any ferns or other plants growing on any road, land, roadside way, roadside bank, or hedge, common, or other place to which the public have access.

Dr. Thomas pointed out that if local authorities would apply for that by-law it would provide for the first time a means of checking the uprooting of many of our beautiful wayside plants which had been proved to be in great danger of destruction. It had been ascertained, he added, that there was no by-law of this description in Scotland at present, but there could be no doubt that a similar danger existed there.

Miss Constance Cochrane, Cambridge County Council and Education Committee, spoke of the ready response of school children to instruction in the care of wild flowers.

The motion that,

> 'The British Association for the Advancement of Science should urge His Majesty's Government to stimulate the employment by local authorities of the powers already conferred upon them by Parliament for the preservation of scenic amenity in town and country,'

was then put from the Chair and carried unanimously.

Session of September 11.

The second and concluding session of the conference of delegates, which had for its object the support of the movement for preserving the scenic amenity of the English Lakeland and its environs, was made an open meeting for all members of the British Association. Having regard

to the circumstance that the discussion was held at a distance from the district and that the audience was gathered from all parts of the British Isles it was considered advisable that the national and even world-wide importance of the English Lakeland scenery should be made clear by addresses on the physical geography and literary associations of the district before proceeding to the paper on regional planning.

Geography of the English Lake District.

By Dr. Hugh Robert Mill.

A circle of fifteen miles radius drawn from a centre on the slope of Dunmail Raise touches the north end of Bassenthwaite Water and the south end of Windermere and includes all the other lakes of the district and practically all the mountains and fells. The land beyond the fifteen-mile circle (except for a junction with the Pennine Upland on the east) is low, spreading to the Solway on the north, the Irish Sea on the west and Morecambe Bay on the south. The highest summits (each 3,000 feet) within the circle include Scafell Pike towards the west, Skiddaw in the north and Helvellyn in the east, each forming the centre of a partially isolated group of ancient pre-carboniferous and volcanic rocks of a highly complicated structure. Unity is given to the complex whole by a system of twelve long, often sinuous, valleys radiating outwards and showing practically no relation to the geology. They probably represent drainage lines originally incised on a dome of vanished rocks elevated in Tertiary times and gradually deepened nearly to base level, leaving between them twelve triangular tongues of elevated land sloping and widening and flattening outwards, which have been sculptured by glacial ice and weather into a variety of forms corresponding to the diversity in texture and hardness of the rocks. Looking from the air above the centre and carrying the eye around the horizon clockwise one would see the valleys of Thirlmere, Ullswater, Haweswater and the Kent diverging from each other at angles of approximately 45° from north to south-east; then the valleys of Windermere, Coniston Water, the Duddon and the Esk each separated from its neighbour by an angle of 30° between south and south-west. The radiate system is continued from south-west to north-west by the valleys of Wastwater, Ennerdale Water and Buttermere-and-Crummock Water, the angles between which are only 15°, and the circle is completed by the valley of Derwent Water and Bassenthwaite Water heading nearly north and making an angle of 30° with its two neighbours.

The control of mobile distribution exercised by this compact and intricate orography is best shown by the distribution of rainfall, the excess of which on the western quadrant of the circle probably accounts for the crowding of the valleys in that sector and the wide spacing of these in the east. On the flat rim of land outside the circle, rainfall varies from 35 to 50 inches per annum, but within it all, except the lower half of Bassenthwaite Water, receives more than 50 inches and within a circle of six miles radius from Dunmail Raise which runs close to the heads of all the larger lakes the rainfall exceeds 80 inches and rises to over 100 inches on Helvellyn and neighbouring heights on the east, and in the west on a large area encircling the heads of Wastwater, Ennerdale Water and Buttermere and extending to within a few miles of the heads of Coniston and Windermere. The intimate sympathy between the isohyets and contour lines of height, having regard to the direction of the prevailing winds, has been proved by careful mapping on a large scale.

The control of vegetation is almost equally clear, and the infinite varieties of height, slope, aspect and climate provide a range from richly cultivated or wooded land to sub-Arctic moors and stony wastes.

All conditions of configuration, climate, soil and vegetation united to dictate the original settlement of isolated communities in the valleys which all turned their least accessible ends to each other and so secured the strong local peculiarities of speech and custom, traces of which still survive.

A note on Wordsworth's Interpretation of Nature.

By Dr. C. H. Herford, F.B.A.

Wordsworth's attitude to scientific study was not to be concluded from some well-known expressions of impatience. He decried the merely analytic use of reason, and demanded the use of the higher reason which he called imagination, and which

included what Bergson called intuition. Like Goethe, but far less consciously and articulately, he was fighting the battle of the organic against the mechanical interpretation of nature. The importance of the poetic view of nature, especially as expressed by Wordsworth and Shelley, had been insisted on by Dr. A. N. Whitehead in his 'Science and the Modern World.' He laid down as 'notions' which Wordsworth had made it incumbent on any adequate philosophy of nature to take account of, endurance, value, organism, interfusion. The present paper attempted to illustrate this important statement so far as Wordsworth was concerned.

(1) *Endurance.* 'Wordsworth was haunted by the enormous permanences of Nature.' This trait had a psychological basis; his tenacity and frugality, his refusal to believe that anything was lost without compensation—'The child was father to the man'; his indifference to action and to event. (2) *Value.* This was implied in every form of what was known as the 'Worship of Nature.' But Wordsworth's special discovery was the significance of common and familiar things. The meanest flower could give him thoughts too deep for tears; and he scorned Peter Bell, for whom a yellow primrose was a yellow primrose, 'and nothing more.' For the modern physicist Man was in danger of insignificance in the presence of the infinitely vast and of the infinitely little. For Wordsworth there was no such disparity. Man and Nature faced one another, closely bound together in their intercourse. Man reached his highest achievement, Nature her destined end. In this conception Wordsworth completely rejected the notion of a merely mechanical relation between them, and, in so far, approached the conception of (3) *organism.* Wordsworth had no biological ideas. But, feeling after the notion of organic union, he fell upon the symbol of marriage. The mind of Man was to be 'wedded' to the universe, and this blending would produce an uplifting and inspiring power. (4) *Interfusion.* But even this symbol did not express all that Wordsworth meant. In the famous Tintern lines he expressed his sense of something pervading both Man and Nature, and found to convey this the word 'interfused,' which Whitehead singled out. But Wordsworth had moods of mystic ecstasy in which even 'interfusion' seemed inadequate, and he apprehended Man, Nature and God as a single unity. Here he lost all relation to modern science, but came into touch with Spinoza. But he did not lose touch with the Lake Country. On the contrary, while the Wordsworth of common and familiar things might have lived and written anywhere, it needed a country of sublime mountain scenery to produce Wordsworth the mystic.

Wordsworth as a Pioneer in the Science of Scenery.

By Dr. Vaughan Cornish.

The pre-eminence of Wordsworth as a poet of Nature has long been recognised, but there is another aspect of his originality which has not yet received adequate recognition. Wordsworth wrote 'A Guide through the District of the Lakes in the North of England with a Description of the Scenery,' which appeared in several editions between 1810 and 1835. The 'Guide' proper is brief, the author regarding this portion of his task as 'humble and tedious,' and he soon plunges into his description of the scenery. Here at once we find scientific originality, for he not only records physical appearances, but also, whenever they give keen enjoyment, seeks the source of the impression, investigating both the objective conditions and the mental qualities concerned in their appreciation. Moreover, he writes in the hope that his essay may lead to habits of 'more considerate observation than have been hitherto applied to local scenery.'

Consideration saved Wordsworth from the sentimental assumption that the aspect of Nature is always harmonious. He points out, for example, a 'defect' in the colouring of the Country of the Lakes. But his faculty of observation made him quick to recognise the conditions in which objects in the view enhance one another, the harmonies which are the true beauties of scenery. Thus he directs attention to the circumstance that the radial arrangment of the English Lakes from a mountainous centre introduces every variety of the sun's shadowing. He points out that the mountains of the district differ from hills not merely in mass but quality, owing to the atmospheric absorption which etherialises the summit when viewed from the valley. He notes the height which must be attained that 'compact fleecy clouds' should settle upon the crest. Among 'the varied solemnities of the night' he recognises the singular charm of stars which 'take their stations above the hill tops'—an excellent observation of enhancement due to a momentary and accidental relation.

He feels the romantic, almost poignant interest of the line of the trees which maintain themselves against the elements at the limit of altitude. The charm of intermingling of field and woodland in the Lake Country he traces skilfully to the progressive agricultural settlement which followed ' the veins of richer, dryer, or less stony soil.' With equal acuteness he indicates how the peculiar economic character of the district has resulted in innumerable lanes and paths which provide the rambler with ' an ever ready guide ' to ' the hidden treasure of its landscapes.'

Although preferring the harmonies of occupation and environment displayed in a highland community of small owners before all other aspects of the scenery of civilisation, Wordsworth pays discriminating tribute to the unique contribution made by wealthy inheritors of landed estate in the preservation of trees beyond economic prime for sheer love of their beauty in venerable age. He notes the geological conditions to which the water of the English Lakes owes the remarkable clearness that makes their depths a magic mirror to lead the mind into ' recesses of feeling otherwise impenetrable.' He does not, however, discover the peculiarities of the watery image which are the source of this mental effect. We must remember that Wordsworth was making a beginning only in the science of scenery, and that with the advantage of another hundred years of accumulated knowledge we can better his instruction. But even so it is remarkable that we should now be taking up the æsthetics of scenery very nearly from the point where he left it, joining hands across a hundred years, rather than proceeding from the mainly orographical studies of scenery produced in the latter part of the nineteenth century.

The ' Guide ' proper and the ' Description ' are followed by the third section of the book, which is on ' Changes, and rules of taste for preventing their bad effects.' Wordsworth dates a more general appreciation of the wilder aspects of scenery from about the year 1775. Thereafter the country of the English Lakes not only attracted visitors, but also, owing to its economic conditions, offered more opportunities for settlement by villa residents than districts parcelled out in great estates. The epoch of railway construction followed, with the result that the changes in the English Lake District in Wordsworth's middle and later life were comparable to those which, owing to the development of motor traffic and the extension of house building, now affect rural England as a whole. Wordsworth points out to the newly-arrived resident that the liking for ' strong lines of demarcation ' and emphatic contrast is due to want of practice, and that if he will pause to study his rural surroundings ' a new habit of pleasure will be formed the opposite of this, arising out of the perception of the fine gradations by which in Nature one thing passes away into another.' The rule that a house situated in mountain scenery should be so designed as to take its place quietly in the landscape is enforced by the penetrating remark that owing to the scale of the view ' a mansion can never become principal in the landscape ' as it may ' where mountains subside into hills of moderate elevation.'

This example of Wordsworth's *flair* for noting the relation of the object of attention to its environment is curiously paralleled by his observation of the effect of the echo of the cuckoo's call from the steep sides of the Rydal Valley. The sound, he says, ' takes possession ' of the valley, an expression which is implicit with suggestion of the important fact that the view is made impressive by any agent which imparts unity to objects the multiplicity of which often prevents the landscape from appearing to the mind as a picture. Here I pause to remark that the sounds and scents of the countryside belong to its scenery. If we did not make the letter *c* soft in the word scenery we should be less apt to forget that the word has no derivational connection with ' seeing.' The visual is no doubt the leading aspect of scenery, but æsthetically we are bound to take account of the simultaneous impression of the natural environment, or scene, upon the other senses. It follows that the societies which concern themselves with the preservation of scenic beauty are within their province in combating unnecessary mechanical noise.

When changes come, Wordsworth is not always apt in recognising a new harmony. His failure to observe the rhythmic reinforcement of rocky pinnacles by trees of pointed form diminishes the efficacy of his protest against the introduction of the larch. His preference for informal lines may have been partly innate but was increased out of measure by intellectual associations, which do so much to cramp the proper functioning of the eye. Thus in the letter to Sir George Beaumont, dealing with the laying-out of grounds, written so early as 1805, which is included as an appendix in Mr. de Selincourt's recent collation of the editions of the ' Guide,' Wordsworth assumes that every person of taste would prefer that the whole garden

should be as near to Nature as possible, and pays no regard to the circumstance that in the immediate vicinity of the mansion it is permissible to prefer formal lines on account of their harmony with those of architecture. Thus, although Wordsworth may have been in advance of his time as an advocate of the free play of the senses, he did not go so far as we now know to be desirable.

Mr. de Selincourt has included as a second appendix letters to the *Morning Post* written by Wordsworth in 1844 on the subject of the proposed Kendal and Windermere Railway. Descending to the dusty arena of practical affairs, his academic mind loses something of its lofty detachment. It is interesting to compare these letters with a recent work entitled ' England and the Octopus,' dealing with the things that to-day impair the peacefulness of our scenery. The style of Wordsworth is indeed less trenchant than that of Mr. Clough Williams-Ellis, but underlying exasperation is almost equally evident. On the whole, however, it is when Wordsworth is dealing with general principles that he is of most service to the cause which so many of us have at heart, the preservation of scenic beauty, and we may well take the concluding paragraph of his ' Description ' as the text of our present appeal for preservation of scenic amenity in the countryside generally and the district of the English Lakes in particular :

' It is then much to be wished that a better taste should prevail among these new proprietors ; and, as they cannot be expected to leave things to themselves, that skill and knowledge should prevent unnecessary deviations from that path of simplicity and beauty along which, without design and unconsciously, their humble predecessors have moved. In this wish the author will be joined by persons of pure taste throughout the whole island, who, by their visits (often repeated) to the Lakes in the North of England, testify that they deem the district a sort of national property, in which every man has a right and interest who has an eye to perceive and a heart to enjoy. '

Regional Planning for the English Lake District.

By Mr. Ewart James.

It was mainly as a result of the development of road traffic that the Lake District was threatened with the same dangers of uncontrolled development as other districts, in the form of unsuitable houses, badly placed, built of unsuitable materials, ' ribbon ' roads, and new motor roads over hills. Once the disease took hold it was fatal. There was no cure for a view screened by a row of houses. It was also stealthy and insidious. There was no shouting in the Market Place, but the next time they went along a certain road they saw two or three more new little dots of bungalows. This was followed by the filling in of the gaps. The result was that a one-time lovely panorama was destroyed for a century.

Invaluable work had been done in the Lake District for many years by three organisations. The first was the Lake District Association. This was founded in 1877, its object being the popularising of the Lake District as a place of residence and as the resort of visitors, by assisting to maintain, in good order, existing roads and footpaths, and rendering points of interest more accessible without impairing their natural beauty. That rule expressed quite frankly and properly the point of view of those thousands of residents whose living depended upon maintaining the popularity of the Lake District as a holiday resort. It laid stress upon ' accessibility ' and publicity while recognising the need for ' preservation.' The Lake District Association had rendered immense public service by the cairning of routes, the defence of public rights of way, the provision of seats and bridges, and in many other ways. Taking them in date order, the next organisation was the National Trust. As its name and its very well known work indicated, this was a national rather than a local organisation, but it had, to all intents and purposes, a Lake District origin, being founded under the inspiration of Canon Rawnsley in 1893. The Trust now held some twenty separate properties in the Lake District. The third organisation, founded in 1919, was the Society for Safeguarding the Natural Beauty of the Lake District. That, again, owed its existence to that greatest of Lake District champions, Canon Rawnsley. It was essentially and strictly a preservation society, seeking to do its work by persuasion and example rather than by compulsion. It, again, had done invaluable work, notably by securing the removal of disfiguring advertisement boards over Dunmail Raise. There would always be useful work for a society of this kind to undertake.

This matter had been taken up by the Cumberland County Council and its Parliamentary Committee. Their action in promoting a conference, with a view to

establishing a Regional Planning Committee for the whole county, had many advantages so far as the Lake District was concerned. It brought in to the aid of the lower rated Lake District the comparatively highly rated towns and industrial regions of the county, and it ensured that the regional plan should be on broad and far-reaching lines, linking up the Lake District with the adjoining sea-coast, the mining region bordering it, and the border region of Carlisle and the northern part of the county, including a long and important section of the Roman wall. The present proposal was that there must be one Regional Planning Committee for the whole of the county, and that that Committee, since it derived its authority and its financial backing from every parish in the county, must formulate a regional planning scheme for every part of the county. Regional Planning and Town Planning were as necessary as sound development, healthy living, and economical administration in an industrial or agricultural district, as they are in a wild uncultivated region such as the Lake District. The principal objects of the plan might, however, be slightly different. In a growing mining and industrial community the main object would be the development of the natural resources with as little damage to the amenities of the district as possible, and proper regard for the health and well-being of the workers. In a rural district the aim would be to aid in securing the well-being of the farming community. The Cumberland County Regional Planning Committee, when it was finally constituted, might find it necessary, for the purposes of convenient working, to sub-divide its very extensive region of 973,086 acres—over 1,500 square miles, and, with the exception of the Greater London Area, considerably the largest regional planning area in the country. Even that did not take into account a considerable area of Westmorland which, it was suggested, should be associated with the Cumberland scheme. That procedure was followed in the case of the Manchester Regional Planning Scheme, with conspicuous success. As the Lake District presented special problems, it was reasonable to presume that the County Regional Planning Committee would treat it as one of the sub-districts under its control and refer it to an area committee for detailed planning.

A scientific method of dealing with a region must be comprehensive, logical, complete, economical. It must be based upon a systematic survey of the region, its structure, history and resources. In the case of the Lake District it must recognise the exceptional character of the region as one of national concern, and must strive to accommodate both national and local claims and rights in the matter of control and responsibility. It must also accommodate the conflicting demands for improved accessibility and preserving its solitude and wild life.

A Regional Planning Scheme, followed by a Town Planning Scheme, would meet all these requirements. It represented mankind's concerted efforts to utilise the resources of a region to their best purpose, and, in the most economical manner, to render its benefits and material and spiritual riches available for the enjoyment of every class of society.

The southern boundary of the Lake District was largely fixed, but the northern boundary was uncertain, owing to the scheme being merged in that for the whole of Cumberland.

The suitability of the Lake District for a Regional Planning scheme was confirmed on geological grounds. The Lake District should be treated as a whole, and also as a matter of special urgency. Paradoxically the natural features which linked the district into one geographical unit kept its parts separate. The Cumbrian mountains formed a barrier, with resultant isolation and lack of co-operation. Owing to this isolation (*a*) hills formed boundaries of three counties; (*b*) there was a constant demand for new roads over the hills in order to reduce distance by road; and (*c*) co-operation was difficult because meetings were rare and costly owing to fares and time occupied on journeys.

So far as regional planning was concerned, the only scheme actually in being comprised a portion only of the south-eastern corner of the Lake District. The Lake District (South) Regional Planning Committee was formed as the result of a conference held at Kendal in August, 1926. It included Ambleside, Windermere, Kirkby Lonsdale, and the South Westmorland Rural District. Grasmere, Kendal. The Ulverston Rural District were invited to join but stood aloof. The area covered by the scheme was 187,283 acres; population 30,162: assessable value £235,880. The district included the whole of the water surface of Lake Windermere, together with the islands it contained, but only one-fourth of its shore frontage, the remainder being in the Ulverston Rural District (Lancashire) and unprotected. Two smaller lakes were included in the scheme, Rydal and Elterwater.

No steps had been taken to promote a scheme for the northern part until February 14, 1928, when he submitted a scheme to the Whitehaven Rotary Club. An informal committee was formed on May 5, with Sir John Randles as chairman. The matter was taken up by the Cumberland County Council on May 23, and their Parliamentary Committee held a successful county conference on July 17. Resolutions were then passed constituting a Regional Planning Committee for the whole county (together with the City of Carlisle and a portion of Westmorland) and agreeing to the expenditure of a rate not exceeding one-tenth of a penny in the £. Those resolutions now awaited confirmation by the twenty-four local authorities in the county.

As originally proposed, the Lake District (North) Region would have comprised the urban districts of Keswick, Millom, Shap, parts of the rural districts of Bootle, Cockermouth, Penrith, Whitehaven, Wigton, and the West Ward of Westmorland. It embraced ten lakes: Wastwater, Ennerdale, Loweswater, Crummock, Buttermere, Bassenthwaite, Derwentwater, Thirlmere, Ullswater and Haweswater, and most of the great mountain groups. The area was 385,423 acres; population 34,119; assessable value £341,431.

By bringing in the whole county the comparative figures became:—

	Area.	Population.	Ass. Value.
Administrative County of Cumberland	968,598	220,463	1,080,091
City of Carlisle	4,488	52,710	320,000
Portion of Westmorland	71,867	3,653	37,221
	1,044,953	276,826	1,437,312

The success of that conference must not be taken too optimistically. The resolutions had still to be confirmed by the respective councils, one had already turned the scheme down, and others had deferred consideration, mainly on the score of expense.

The southern Lakeland scheme had provided for a maximum expenditure of a fifth of a penny in the £ for three years. With the areas now contributing this would produce £195 per annum, a total of £585. The necessary survey was costing £390.

On the same basis the survey for northern Lakeland would have cost £800, and to leave a margin for organisation expenses, £1,000 would have been required, to produce which a rate of ¼d. in the £ for three years would have been required. With the far greater rateable value rendered available by the extension of the scheme to the whole county and the City of Carlisle, it was estimated that a rate of one-tenth of a penny in the £ for three years would be sufficient. This would produce (allowing for possible fall in assessment to £1,300,000) £540 a year, or a total of £1,620, which should be ample for the purpose. The tenth of a penny rate for three years was a final payment for the Regional Planning Scheme, which did not necessarily involve any further expenditure for purchase of land, compensation, public works, or legal or administrative expenses. For that sum the County would secure an exhaustive survey of its resources, needs, and possibilities, not only as regarded preservation of amenities, but also as regarded roads, housing, public services and industrial developments.

Detailed planning should be left to the committee, but one or two suggestions might not be out of place. Improved access to west and south-west of the Lake District by road or rail was desirable; external circumferential roads might be permitted, but through roads should be resisted, for the Lake District could only be thoroughly appreciated by those who walked through it and climbed its hills.

A National Lake District Defence Fund should be opened with a guarantee fund of a substantial amount. This would be utilised for necessary compensation and purchase of land where the regional and subsequent town planning schemes showed this to be necessary.

On the motion of the President it was agreed that the Conference of Delegates should express sympathetic interest in the effort to prepare a

comprehensive scheme for preserving the scenic amenities of the English Lake District and its environs.

A communication was received from Dr. A. Loir inviting the attendance at the Havre meeting of the French Association of those delegates who did not accompany the British Association to South Africa in 1929.

A communication was received from the Cape Natural History Club to the effect that the Secretary (address, P.O. Box 2286, Cape Town) would be pleased to put delegates on arrival into touch with persons having local knowledge of their several subjects, and that meanwhile information could be obtained from Miss Edith L. Stephens, Librarian and Vice-President, whose address until January would be 1 Birchington Road, London, N.W. 6.

A letter was received from Mr. Harold Peake asking delegates to send particulars of any recent discoveries of Bronze Implements to him c/o Society of Antiquaries, Burlington House, London, W., in order that the finds might be included in the catalogue.

REFERENCES TO PUBLICATION OF COMMUNICATIONS TO THE SECTIONS

AND OTHER REFERENCES SUPPLIED BY AUTHORS.

The names of readers of papers in the Sections (pp. 533–638), as to which publication notes have been supplied, are given below in alphabetical order under each Section.

References indicated by 'cf.' are to appropriate works quoted by the authors of papers, not to the papers themselves.

General reference may be made to the issues of *Nature* (weekly) during and subsequent to the meeting, in which summaries of the work of the Sections are furnished.

Section A.

Green, Dr. G.—To be published in *Phil. Mag.*

Haas, Prof. W. J. de.—Part to appear in *Journ. de Physique*, Paris. Cf. 'On the Magnetic Disturbance of the Supraconductivity with Mercury,' I and II, *Proc. Roy. Acad. Amsterdam* **29** (1925), no. 2, p. 233 and p. 250 (Comm no. 180*d* from the Physical Laboratory of Leiden, W. J. de Haas, G. J. Sizoo and H. Kamerlingh Onnes); 'Further Measurements on the Magnetic Disturbance of the Supraconductivity with Tin and Mercury,' by W. J. de Haas and G. J. Sizoo, *ibid.* **29** (1926), no. 7, p. 947 (Comm. no. 180 from the Physical Laboratory of Leiden); 'Research about the question whether Grey Tin becomes Supraconductive or not,' by W. J. de Haas, G. J. Sizoo and J. Voogd, *ibid.* **31** (1927), no. 3, p. 350 (Comm. no. 187*d* from the Physical Laboratory of Leiden); 'Rigidity of Supraconductive Metals,' by W. J. de Haas and M. Kinoshita, *ibid.* **30** (1927), no. 5, p. 598 (Comm. no. 187*b* from the Physical Laboratory, Leiden); 'Over de weerstandshysteresisverschijnselen van tin, lood, indium en thallium bij de temperaturen van vloeibaar helium,' door W. J. de Haas en J. Voogd, *Kon. Akad. van Wetenschappen*, Amsterdam, deel **37** (1928), no. 6, p. 582; 'Nieuwe suprageleiders,' door Edm. van Aubel, W. J. de Haas en J. Voogd, *ibid.*, Amsterdam, deel **37** (1928), no. 7, p. 706; 'Over de suprageleiding van het Gallium,' door W. J. de Haas en J. Voogd, *ibid.*, Amsterdam, deel **37** (1928), no. 7, p. 702.

Jackson, Dr. J.—Cf. *Monthly Notices*, R.A.S. **88**, p. 465 (Mar. 1928); *Nature*, June 2, 1928.

James, R. W.—Cf. James and E. M. Firth in *Proc. Roy. Soc.* A **117**, p. 62 (1927); I. Waller and James, *ibid.*, p. 214; James, Waller, and D. R. Hartice, *ibid.*, **118**, p. 334 (1928); James and Brindley, to appear *ibid.*

Jones, Prof. E. Taylor.—To appear in *Phil. Mag.*, cf. *Proc. Roy. Phil. Soc. Glasgow*, **56.**

Martyn, D. F.—Cf. *Phil. Mag.*, Nov. 1927 and July 1928.

Watt, R. A. Watson.—*Union Radio Scientifique Internationale*: proc. General Assembly, Brussels, Sept. 1928.

Section C.

Allan, Dr. D. A.—Expected to appear in *Trans. Roy. Soc. Edinb.*; cf. *ibid.* **56**, pp. 57–88, 1928.

Andrew, G.—(*a*) *Mem. and Proc. Manchester Lit. and Phil. Soc.*, **14**, pp. 205–9, (*b*) *ibid.* **15**, pp. 210–19.

Campbell, Dr. R.—Expected to appear in *Trans. Roy. Soc. Edinb.*; cf. *ibid.* **48**, pt. iv, no. 34 (1913).

Macgregor, A. G.—Expected to appear in *Trans. Roy. Soc. Edinb.*

Richey, J. E.—Probably to appear in *Q. J. Geol. Soc. London.*

Spencer, Dr. W. K.—Results appearing in *Monographs Palæont. Soc. Gt. Britain*, pts. i-vii (1914–27).

Arrangements are contemplated for the publication of contributions to the discussion on the Tectonics of Asia.

SECTION D.

Ashworth, Prof. J. H.—Cf. *Proc. Roy. Soc. Edinb.* **47**, pp. 81–93, with map (1927).

Bidder, Miss A. M.—Partly (with Dr. Ad. Portmann) in *Q. J. Micr. Sci.*, autumn, 1928.

Browne, Prof. F. Balfour.—Cf. 'The Evolution of Social Life among Caterpillars,' in *Verh. III Internat. Ent. Kongresses*, Zurich (1925), pp. 334–40.

Carter, Dr. G. S.—(On Aeolid Veliger) *Brit. Journ. Exp. Biol.* Cf. *Proc. R. S. B.* **96**, p. 115 (1924) ; *Brit. Journ. Exp. Biol.* **4**, p. 1 (1926). (On Paraguayan Chaco) *Journ. Linnæan Soc.* Cf. *Proc. Roy. Phil. Soc. Glasgow* **56**, p. 82 (1928).

Clark, Prof. A. J.—*Journ. Physiol.* **66**, p. 185 (1928).

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APPENDIX

To the Report on Animal Biology in the School Curriculum.

Suggestions for Schemes of Biological Study in the Secondary School.

After discussion with a number of teachers the following suggestions are made, though it is realised that there are also other reasonable ways of arranging the work. The Committee would indeed at this point call attention again to the closing paragraph of the first section of this Report.

It is expected that some Nature Study work will already have been done at an earlier age, and it is understood that throughout the course every opportunity of studying the living animal will be utilised.

Work prior to Schemes A and B.

In some secondary schools the pupils commence at age 11 plus, and the work of the school is based on a five-year scheme before School Certificate. In such cases the first year affords an admirable opportunity for carrying out some carefully arranged nature study.

At this stage the work in biology and in physics should be very carefully co-ordinated. Should it be possible it would seem best that the teaching should be in the hands of the same teacher, though it is realised that this may not generally be permitted by the conditions of school organisation.

Animals and plants should at this stage be studied in relation to seasonal change. In autumn they may be observed before the winter rest; their winter condition may next be observed; and in the spring the budding of trees, germination of seeds and conditions of growth, awakening of hibernators, return of migrants, nests and eggs, and life-histories of frog and insect, may be studied. The biological seasonal change should be correlated with changes in the environment, and for the latter purpose charts could be kept indicating seasonal changes in temperature, length of day and altitude of the sun. The metric rule may be used in measuring leaves, &c., to obtain data regarding variation which may be expressed by means of graphs. In the spring the rapid growth of plant and animal can be investigated with some accuracy by the use of the metric rule. Simple ideas of solution and of the physical properties of water and air may be linked with the study of germination.

Scheme A.

Suggestions for a Four-year Scheme leading to School Certificate Standard.

First and Second Years (12 *plus and* 13 *plus*).

The work of these years should consist of some simple study of the structure and physiology of a flowering plant and of a mammal, a consideration of human physiology and hygiene being associated with the latter.

The importance of sun to all living things. The green plant as physiological link between the animal and the non-living world.

During these years the physiological work will not necessitate a knowledge of Chemistry.

It would be useful at this stage if the Physics or other course should include some study of solids, liquids and gases, also simple idea of diffusion in liquids and gases; the sun, seasonal changes, day and night; the moon and its phases.

The work upon soil included under (*a*) below may be expanded a good deal, particularly in agricultural districts.

It has been thought important to arrange the content of the syllabus for the first and second years in such a way that, taken together, they furnish a course possessing a certain completeness in itself; this is to provide for the case of any schools which may not be able to arrange for the continuance of Biology beyond a second year except for those who proceed to the School Certificate standard.

Suggested Syllabus.

The essential functions common to living organisms, as illustrated by flowering plant and mammal. Attention should be given to structure for the elucidation of function ; the mammal need not be dissected by the pupils themselves, but a dissected specimen should be shown to them. The differences between the animal and green plant are also to be noted, and related to the motile and stationary habit respectively ; the difference in habit being related in turn to difference in nature of raw food material.

(*a*) *Nutrition :* Raw material of food of green plant. Simple experiments, by use of sieves or otherwise, to ascertain the proportions of water, clay, silt, sand, gravel and organic matter in a sample of local soil. Culture of plants in distilled water and soil water. Soil water shown by evaporation to contain dissolved mineral matter ; comparison with transpired water suggests that the matter is retained by the plant. Suggestion confirmed by examination of ash of burnt plant. Examination of external features of root, and of a section in order to see conducting tissue. The adaptations of the green leaf that enable it to absorb sun-energy and carbon dioxide. Experiment to test for starch in evergreen leaf ; in variegated leaf. Experiments on relation of light and darkness to starch formation. Dependence of animal life on the green plant. Examination of mouth of mammal, and of the rest of the alimentary canal in a dissected specimen. Experiment to show digestion of starch by saliva. Transport and storage in plant and animal. Importance to man of a mixed diet.

(*b*) *Excretion :* The elimination of the waste products of katabolism. In green plant confined virtually to water and carbon dioxide (covered by experiments under Respiration). In animal includes also elimination of nitrogenous material. Examine kidneys and ureters in a dissected mammal. Excretory function of human skin. Hygiene.

(*c*) *Respiration :* Oxygen is necessary to life. Experimental proof in case of plant. The liberation of energy is associated with the oxidation process. Two of the waste products resulting are carbon dioxide and water. Experiment to show that carbon dioxide is given off by the green plant (use a rapidly growing plant). Examination of lungs, diaphragm, and ribs in a dissected mammal. Experiment, by breathing into lime water, to show that man gives off carbon dioxide. Also show that water is given off both by green plant and man. Blood in relation to respiration. Red blood corpuscles. Hygienic breathing. Ventilation.

(*d*) Résumé of functions of *transport* system which will have been referred to in dealing with *a*, *b*, and *c*, above. Note in the animal the white blood corpuscles. Brief reference to hormones. Structure of heart in mammal. Experiment to show use of valves by running water into sheep's heart. Count pulse beats in several persons and estimate the average rate of beat. Distinction between arteries, veins and capillaries. (The names and detailed distribution of the blood vessels are not required.)

(*e*) *Sensitivity :* Experiments to show reactions to external stimuli (gravity, light and heat) by different plant members. Central and Peripheral nervous system of mammal. Sensory and motor nerves. Co-ordination of the functions of the animal body through the nervous system, and of the animal, as a whole, with the external world. The external features of the mammalian brain should be examined in a hardened specimen of a sheep's brain. Some large nerve should be seen in a dissected animal. Reflex Action. Instincts. Eye of Ox should be examined, and some experiments on human vision be carried out.

(*f*) *Reproduction :* Sperm (examine contents of spermatheca of Earthworm) and Ovum (spawn of Frog). Essential character of fertilisation. Distinction between fertilisation and reproduction. Experimental proof of fertilisation in flowering plant. A cross pollination experiment may also be utilised in relation to heredity. (The complication of the alternation of generations in the flowering plant may be omitted.)

(*g*) *Growth and Development :* Examination of the ovaries and placentation of one or two flowers, e.g. daffodil, snowdrop, and of some ripening fruits, e.g. tomato, with emphasis on the course of the conducting tissues along the placenta and their function in relation to the food supply of the ripening seeds, followed by a reference to the analagous type of arrangement in the mammalian uterus. Observations on growth and growth changes of living plant ; and of caterpillar and tadpole to completion of metamorphosis.

(*h*) *Skeleton :* The diffuse skeleton of the plant in relation to its sedentary habit. The compact skeleton of the mammal and its association with the muscular system in relation to locomotion. The calf muscle of a dissected frog may be examined and its action investigated. The actions of the levers of each of the three orders should be illustrated by movements of the human foot and forearm. The protective function of the skeleton. (The names of the bones are not required at this stage.)

Third Year (14 *plus*).

Field, aquarium or school garden work should be undertaken this year, involving a study of the interrelations of living organisms, animals and plants, with one another and with their environment. The stress is now upon the web of life rather than upon the seasonal change studied in the earlier years.

Some study of lower organisms illustrating the increasing complexity of the organisation of the body.

Suggested Syllabus.

Autumn Term.

1. Some tropic responses: e.g. heliotropism, geotropism and hydrotropism in growing plants, and experiments also to illustrate response of Planarian or Daphnid to light, heat and gravity.

2. The single cell as an organism, illustrated by the structure and functioning of Amœba, Paramecium and Euglena, Chlamydomonas or Protococcus.

3. The organisation of cells into more complex individuals, Spirogyra, Volvox, Hydra. Mucor as showing a simple type of multicellular structure; its mode of nutrition. Some reference may be introduced here to bacteria and their relation to the soil and to disease. The nitrogen cycle.

Spring Term.

1. Organisms illustrating differentiation of organs with division of labour.
   (*a*) The Fern.
   (*b*) The Earthworm. External characters. Alimentary canal, nervous and excretory systems to be examined in a dissected specimen by the naked eye and hand lens. (Reproductive organs not required.)

2. Increasing complexity of organs of locomotion, illustrated by Planarian, parapodia of Nereis, leg and wing of Butterfly.

3. Increasing complexity of anterior end of animal as a head. Illustrated by external features of Planarian, Nereis and Butterfly.

Summer Term.

The study of living plants and animals on the lines indicated above.

Fourth Year (15 *plus*).

Revision of the structure and physiology of the flowering plant and mammal. An elementary knowledge of Chemistry will be found useful at this stage as bearing upon the subject matter of physiology. For example, experiments may be carried out to determine the elements necessary for the growth of plant in culture solutions; Fehling's test may be used in relation to digestion of starch by human saliva, and similarly the action of pepsin may be investigated. The mammalian eye may be briefly considered, and experiments performed upon skin sensation. Further study of human physiology and hygiene.

Immensity of space and time. Some slight reference to extinct monsters, illustrating how animals have changed. Evidences of Evolution. The recent introduction of Man.

The relation of Man to his biological environment. His disturbing influence. Civilisation based on the domestication of plants and animals. The history of a few selected food plants and animals, including brief reference to one or two of their insect and worm pests. Insects as carriers of human diseases. Vegetable and animal products in industries and manufactures, *e.g.* cotton, timber, paper, wool, silk. Any other relations of the study of biology to human affairs as illustrated by local conditions.

(The subject matter of the last two paragraphs will necessarily be treated briefly, upon essay lines.)

Scheme B.

Suggestions for a Two-year Scheme to be taken by all Pupils.

(An alternative scheme would be the first two years of Scheme A.)

This scheme comprises the essentials which it is considered should be taught to every boy and girl without relation to any special examination requirements. It has been framed as introductory to studies of vital importance and interest which may be followed up by reading, making possible an intelligent interest in the progress of modern thought and of health legislation, local and national.

The tandem arrangement has been adopted as a method of approach alternative to that followed in Scheme A, and as a further alternative the study has been commenced with the simpler forms. It should be stated however, that, with one dissentient, the members of the committee prefer the intimate association of the animal and plant throughout the course of study, and that the course should commence with the higher forms.

It is expected that some Nature Study work will already have been done at an earlier age, and it is understood that throughout the course every opportunity of studying the living animal will be utilised.

First Year (12 *plus*).

The work of this year should consist of :—

1. The study of a graded series of animals beginning with Amœba and including also Paramecium, Hydra, Insect with metamorphosis, and Frog, and leading up to a knowledge of human physiology. At every step reference should be made to parallel processes in the human organism.

2. A study of plants beginning with the simplest green plants, including Protococcus and Spirogyra, exemplifying plant nutrition and culminating with the flowering plant. The substance of the plant portion of Section (*a*) of the Syllabus for First and Second years in Scheme A should be included here.

Second Year (13 *plus*).

The work of this year should consist of :—

1. A more detailed study of human physiology associated with the dissection of a small mammal such as a rat. (It would be sufficient for the teacher to show already dissected specimens.)

2. A study of plants which afford food material to man and whose products are used in industries and manufactures.

INDEX.

References to addresses, reports, and papers printed in extended form are given in italics.

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